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AN ASSESSMENT OF THE FOUR ELECTRODE METHOD FOR SOIL SALINITY MEASUREMENT

by

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ABSTRACT

The four-electrode method of soil salinity measurement has been touted as a quick, relatively inexpensive technique for surveying salt-affected soils directly in the field. Its accuracy, however, is affected by field moisture content, soil temperature and texture. This study evaluates the method and compares field soil salinity data to laboratory data under conditions of varying soil moisture content and soil temperature.

Salinity at three areas near Nobleford, Alberta where saline seep activity had been observed, was evaluated using the four-electrode method. Electrical conductivity of soil samples collected at the same time was determined in the laboratory using the saturation extract method. The two methods were compared using multiple regression techniques and electrical conductivity contour maps were prepared using data from each method. The maps were then compared visually. Surveys were conducted during periods when moisture and temperature variations within the soil profile were high, and during periods when the variations were low. In addition, six sites were instrumented for measurement of soil moisture content, soil temperature, water table level, and electrical conductivity using salinity sensors. Soil salinity fluctuations derived from four-electrode measurements at these sites were compared with those obtained from salinity sensor data.

Results show that the area of measured soil salinity greatly exceeded the salt-affected area as indicated by observing crop behavior. The presence of extremely localized patches of high salinity also indicated that discharge may be moving through fissures and joints within the till. When variations in the soil salinity ranged from non-saline to saline, four-electrode ECa and saturation extract ECe had correlation coefficient (r) values exceeding 0.90 despite variations of soil moisture content and soil temperature within the survey area. Where the soil was more uniformly saline, the r values dropped considerably and ECa required correction by the inclusion of variables for texture, soil moisture, and soil temperature in order for the r values to exceed 0.70. Soil salinity contour maps, as derived by the two methods however, showed reasonable agreement in all cases.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

Page

I. INTRODUCTION

Soil salinization has been a problem for man for many centuries. The Mesopotamians first recorded scattered patches of recent salinization about 2400 B.C. Salinization grew to be such a problem that historians consider it to be one of two primary factors that brought about the end of the Mesopotamian civilization.

Traditionally soil salinity has been associated with the water table rise brought about by irrigation. Of more recent concern, however, is the salinization of soils in dryland areas. This condition is brought about by the discharge and seepage of groundwater carrying dissolved salts. It accounts for the majority of salt-affected area in North America and unlike the salinization of irrigated lands, the source of recharge is not always easy to identify or control.

On the Northern Great Plains of the United States and the southern Prairie Provinces of Canada salinization of dryland is a major problem facing agriculture today. Several studies have attempted to quantify the problem. Saline soils account for over 2.4 million ha in total, while Alberta has over 100,000 ha of dryland seriously affected by salt, and another 400,000 ha affected to a lesser degree (Vander Pluym, 1978). In some areas up to 16 percent of the arable land is affected. Over 22 percent (80,000 ha) of all irrigated land in Alberta is salinized enough to reduce crop growth (McCracken, 1973). The problem is of concern abroad

as well; Australia has over 78,000 ha of previously productive farmland affected by dryland salinization, with an estimated increase of 1 percent per year (Peck, 1978).

The problem is serious not only due to its extent, but also because it is increasing at a alarming rate. Data from Vander Pluym (1978) showed that the salt-affected area of the Peigan Reserve doubled for rangeland and tripled for cultivated land over a ten-year period from 1961 to 1970. A Montana survey showed that over the entire state, salt-affected area tripled in size from 20,480 ha to 60,000 ha in a sixteen-year period. In North Dakota, a farmer survey in Hettinger County showed that 51 percent of the observed saline seeps have occurred since 1960 (Doering and Sandoval, 1976).

Groundwater associated with saline seeps tends to discharge in irregular patches that are scattered throughout a field. The result is that a field becomes so dissected by salt patches and wet areas that it becomes impractical to cultivate with large mechanized equipment. The entire field is therefore used for some less-productive purpose or else removed from agricultural use completely. Thus the area rendered less-productive because of salinity exceeds the area directly affected by salt.

Salinization begins when the groundwater rises into or near the rootzone long enough for salts to accumulate by evapotranspiration. Sometimes this condition is reflected by the crop producing lush growth in a small patch above the

discharge area. This is a result of a favorable moisture and nutrient supply provided by the groundwater. With time, the crop growth becomes stunted or ceases altogether on the patch, due to increased salinity levels, and salt tolerant weeds succeed. The condition can be stabilized by removal of the discharging water, either by insertion of subsurface drains or a change in land management practices. Accumulated salts must then be leached away, but this can be a slow process. Often by the time the symptoms of saline seepage become visible, too much salt has accumulated for removal during a practical time span. A more reliable method of early detection, rather than observing crop behavior, is required in order that salinization can be identified while reclamation is still a relatively simple procedure.

An established method of salt evaluation is to survey the land and sample the soil for laboratory analysis. This procedure is time consuming and expensive for the resolution required to detect salt encroachment. A less expensive technique, the four-electrode method, which measures soil salinity directly in the field, has been developed by Halvorson and Rhoades (1976). At the present time, though, there is a need for field testing this method under the conditions encountered during the growing season in a setting such as southern Alberta. This would serve to increase the data base of the four-electrode method for till-derived soils of the Prairie Provinces, and provide more information on the usefulness of this technique during

periods of varying soil moisture and soil temperature.

The major objective of this study is to evaluate the four-electrode method for surveying saline lands in southern Alberta by comparing the data and salinity contour maps from the four-electrode measurements to those from sampling and laboratory analyses. In addition, four-electrode data from specific, instrumented sites were compared to salinity sensor data in order to evaluate its effectiveness in estimating in situ salinity fluctuations during the growing season. This study has been undertaken as a co-operative effort between the Department of Soil Science at the University of Alberta, and the Soils Section of the Agriculture Canada Lethbridge Research Station.

II. CAUSES OF DRYLAND SALINITY

Dryland salinity is a condition occurring on non-irrigated land where salts, translocated by water, accumulate within the root zone as a result of evaporation exceeding precipitation. A saline seep is a recently developed wet, salty area in non-irrigated soil on which crop production has been reduced or eliminated (Peck, 1978). Dryland salinity is thought to most often occur as a result of saline seeps in various stages of development. Unlike the salinization of irrigated land, which has been known for several thousands of years, the salinization of dryland has become recognized as a problem only within the last century. On the Northern Great Plains of North America, salinization mainly occurs in soils of the glaciated regions, although it can develop in non-glaciated soils as well. In Canada it is generally restricted to the semi-arid region of the Prairie Provinces, but it has been observed as far north as the Peace River District of Alberta (A. Hennig, 1980, personal communication).

Saline seeps develop as a result of a combination of geologic, hydrologic, and cultural factors. These factors will form the topics of a more detailed discussion.

2.1 GEOLOGICAL CONSIDERATIONS

2.1.1 Bedrock Geology

The bedrock geology of the Canadian portion of the Northern Great Plains is dominated by sandstones and shales from the

Upper Cretaceous Epoch. The interior plains region was at this time a low area that served as a depositional basin for the waters from the Canadian Shield to the east, and the rising Rocky Mountains to the west. The basin was extensive, including all of the Northern Great Plains, and lasted throughout the Cretaceous Period and into the early Tertiary Period. During the Cretaceous Period, tectonic activity caused the sea to advance and retreat several times. During advances, marine shales such as the Pakowki and Bearpaw formations were left behind, while during major retreats, coarser textured freshwater deltaic sediments such as the Belly River and St. Mary's River formations were deposited. Minor shoreline fluctuations often resulted in an interbedding of marine and deltaic deposits within some of these formations. During times of recession, broad swamplands developed on the floodplains of low-gradient meandering rivers. These swamps became the birthplace of the extensive lignite and sub-bituminous coal beds found today in Cretaceous deposits.

The last major advance of the sea occurred around the close of the Cretaceous Period, about 65 million years ago. With the coming of the Tertiary Period, the Northern Great Plains were above sea level, producing broad areas of swampland and flatland into which freshwater sediments from the west were deposited. These deposits have been eroded from most of the Canadian plains but they form a significant portion of the bedrock of Montana and North Dakota. An

example is the lignite-bearing Fort Union Group. By the late Paleocene Epoch, uplift and erosion had produced several large drainage systems consisting of deep, dry, broad, mature valleys which dissected the plains into plateaux. Drainage from the Canadian Plains as well as the ancestral Missouri and Yellowstone Rivers was into Hudson Bay (Westgate, 1968). It was in this period that all major topographic features of Alberta, Saskatchewan, and Montana (e.g. Cypress Hills) were formed.

There is evidence to suggest that in southern Alberta, the area east of the foothills was subjected to only one major glacial advancement, the Laurentide continental sheet during Wisconsin time (Bayrock, 1969). As the glacier retreated approximately 15,000 years ago, texturally unsorted morainal debris associated with it, along with texturally sorted glaciofluvial and lacustrine deposits, were left behind. Often these deposits were left one on top of the other, depending on the local nature of the deposition processes. Most of the plains were covered with unsorted morainal material (till) ranging from two metres in thickness to over 100 metres in buried river channels. Glaciation is responsible for the minor topographic features such as the rolling landscapes seen on the prairies today.

Glacial till is primarily derived from the local bed-rock, which implies that those tills derived from marine shales are high in soluble salts. Pawluk and Bayrock (1969) found that the salt distribution has apparently been altered,

however, by postglacial groundwater flow. They also found that the most common salt present in till samples from central and southern Alberta is sodium sulfate. Sodium ions are also the dominant exchangeable cations found in most marine shales (Moran and Cherry, 1977).

2.2 HYDROLOGICAL CONSIDERATIONS

2.2.1 Climate

The general climate of the saline seep-affected areas of North America (southern Alberta, southern Saskatchewan, Montana, North and South Dakota, and northern Wyoming) can be summarized by stating that the growing season has warm, sunny days with frequent winds and variable precipitation. Southern Alberta and Montana have weather that is strongly influenced by the mountains and Pacific Ocean to the west. Weather systems spawned in the Pacific Ocean move eastward but usually lose all their moisture by the time they cross the Rocky Mountains, and are often only windstorms when they cross southern Alberta. In the summer, the high pressure systems that build northward through Montana into southern Alberta are stable and provide clear skies and warm temperatures for several days at a time. Precipitation in the summer occurs frequently from daily convective processes and is very local in nature. In the winter, stable air masses come from the north but are frequently interrupted by westerly winds (chinooks) that produce rapid temperature

rises and a high amount of snow cover removal in a short space of time.

In Alberta, dryland salinity occurs where mean annual precipitation ranges from 350 to 460 mm (McCracken, 1973). Long term observations recorded in Lethbridge show that 70 percent of mean annual precipitation falls between April first and September thirtieth with 32 percent of the yearly precipitation occurring in the months of May and June (Hobbs, 1977). Potential evapotranspiration is greatest during the months of June, July and August.

Evapotranspiration at the sites of groundwater recharge serves to offset the effects of summer precipitation. In North Dakota, measured evapotranspiration is at least 2 to 5 times greater than precipitation during the months of June and July (Rehm et al., 1982). As a result, the local nature of summer storms, coupled with high rates of evapotranspiration, tend to make recharge a rare and isolated event during the summer. For example, Freeze and Banner (1970) have found that only one rainfall event during a 14 month period, 3.8 inches in two days, led to a water table rise at Good Spirit Lake, Saskatchewan. Van Schaik and Stevenson (1967) found that a net rainfall of greater than 150 mm between June 1 and November 1 was needed before a one metre-deep water table in bare clay-loam soil would rise. Freeze (1969) determined mathematically that low-intensity rainfalls of long duration are more likely to produce recharge than high-intensity rainfalls of short duration.

Most recharge on the Canadian Prairies occurs as a result of snowmelt in the spring. Freeze and Banner (1970) conclude that recharge is variable with area, since snowmelt tends to pond in depressions before infiltrating to the water table. Since snowmelt often occurs before the soil has completely thawed, the location of recharge areas is complicated further, as frozen depressions will present a barrier to infiltration and soil water movement.

The effect of evapotranspiration at the sites of groundwater discharge is to concentrate salts by removal of water in vapor form from the soil surface, and also by increasing the water demand on plants. Since plant roots extract relatively pure water from the soil, increased rates of transpiration will increase the rate of salt concentration in all soil water accessible to roots. Plant transpiration coupled with soil capillary forces serve to concentrate salt in soil not only when the water table is close to the surface, but even when it rises near the vicinity of the root zone.

Rainfall at a discharge site will produce a water table rise on frequent occasions during the growing season. The reasons are three-fold:

(i) surface runoff from upper slope positions will increase the probability of ponding in lowerslope depressions,

(ii) the soil at a saline seep site contains more moisture than similar soil in a recharge position,

increasing the likelihood of transmitting precipitation to the water table, and

(iii) the water table is usually at a shallow depth, which implies that there is less distance for the water to move.

Temperature may also play an important role in recharge and discharge on the Canadian Prairies. Taylor and Cary (1960) showed that a thermal gradient may cause large quantities of water to move in the liquid phase. Meyboom (1967) and van Schaik and Rapp (1970) have noted evidence of moisture movement in frozen soils on the Canadian Prairies. Willis et al. (1964) found that upward movement of water from shallow water tables to the freezing front may produce enough moisture increase in the soil to make fall irrigation unnecessary. Van Schaik and Rapp (1970) have also found that shallow water table recessions during the winter can be offset by infiltration of snowmelt-waters during chinooks.

2.2.2 Soil Moisture Movement

The initial observations about water movement through a porous medium were made by Darcy in 1856, who empirically determined that the volume flux of water is proportional to the hydraulic gradient. The flux and gradient are related by a proportionality constant, hydraulic conductivity, which is a property of both the fluid and the conducting medium. For a given fluid, such as water, the hydraulic conductivity becomes related to the medium and therefore pore geometry

becomes the critical factor in conduction. Similarly pore size becomes critical, and as the Hagen-Poiseiulle equation demonstrates, the smaller the pore size the greater the resistance to flow.

Hydraulic conductivity decreases with the decreasing moisture content of the medium. In a draining soil the larger pores empty first, and subsequent water movement must take place through the smaller pores, therefore reducing the rate of water movement. Reductions in hydraulic conductivity of a saturated soil when it becomes unsaturated can often be several orders of magnitude. Pore geometry and size are important in this aspect as well. The hydraulic conductivity of clay soils does not decrease with decreasing water content as rapidly as does the hydraulic conductivity of sandy soils, since the smaller pores of the clay soils tend to remain available for conduction at low moisture contents. It is possible for a clay soil to have a higher hydraulic conductivity than a sandy soil under low moisture conditions.

The theory of water movement through homogeneous, isotropic media is useful for initiation into the theory of the water movement processes, but in most cases it is not applicable to field conditions, especially in glaciated terrain. Textural changes will alter the moisture-holding and moisture-conducting capacities of a soil. For example, if a coarse textured soil overlies a finer textured layer, a wetting front moving downward through the coarse textured

soil will be slowed as the fine pores attempt to handle the volume delivered by the overlying larger pores. If the underlying soil has a high clay content, swelling of the clay minerals may further constrict the flow passages. The result can lead to a zone of saturation in the coarser textured layer. Day and Luthin (1956) showed evidence to support this in laboratory columns using a very fine sandy loam overlying a loam. Similarly if a wetting front moves through a fine textured layer overlying a coarser textured one, it is temporarily impeded at the textural discontinuity until the tension decreases enough in the fine pores to allow the water to enter the large pores. If the difference in pore size is great enough, tensions approaching zero (saturation) are attained in the overlying layer. Therefore, layered soils offer restrictions to water movement, and these restrictions can lead to the formation of a saturated zone or perched water table.

2.2.1. Infiltration

When water is applied to the soil surface, there are three possibilities for its immediate redistribution. It can enter the soil (infiltration), pond upon the surface (detention) or flow over the surface (runoff). Soil properties, intensity of water application, and time are some of the variables that determine the quantity of water that infiltrates, and the quantity which ponds or runs off. The relationship between infiltration and runoff has been

the subject of many studies and models. One of the first such studies was a theoretical approach by Green and Ampt (1911), which states that at the initial (t=0) application of water, the infiltration rate, defined as the volume of water entering a unit surface area per unit time (volume flux) is high and decreases with increasing time to an asymptote of steady flux. Horton (1933) found that each soil has an ultimate limit to its infiltration rate when the rate of water application was greater than the rate of infiltration (ponding conditions). This "infiltration capacity" was a result of empirical studies, and like Green and Ampt's model it shows that the maximum rate of infiltration decreases with time, approaching a constant value. This decrease is brought about mainly by the filling of soil pores with water, and therefore the rate of decline is dependent on the soil porosity. Fine-textured soils have a faster rate of decline and a lower limiting value than do coarser-textured soils.

Rubin and Steinhardt (1963) and Rubin et al. (1964) were able to predict Horton's "infiltration capacity" at a given time providing that information regarding soil moisture characteristic curves, initial soil moisture and intensity of water application were known. They showed that the final constant infiltration rate in the Horton model was equal to the saturated hydraulic conductivity. This can be explained by considering the forces involved in infiltration. When water enters an unsaturated soil, the

forces acting upon water movement are both matric and gravitational. As the wetting front deepens, the matric potential gradient between the saturated zone and the unwetted soil decreases. As the upper portions of the soil approach saturation the matric gradient approaches zero, leaving the significant influence to gravity. As a result the flux approaches that determined by saturated hydraulic conductivity. Therefore in order for ponding to occur, water application (rainfall) must be greater in intensity than the saturated hydraulic conductivity of a soil and longer in duration than the time required for the soil to reach the final constant infiltration rate.

In the 1950's, researchers began a trend toward reducing the number of characterization measurements that had been required in the earlier empirical studies by establishing sound mathematical descriptions of the physical processes occurring during infiltration. At the same time more complex mathematical relationships were required to make the models more realistic. Philip (1957a-f, 1958a,b) developed a mathematical equation for one dimensional vertical flow, both downward and upward (capillary rise), and solved it by analytical methods. This enabled the prediction of wetting front profiles at successive times for an infinitely deep Yolo clay loam, after establishing the hydraulic conductivity and diffusivity relationships with moisture content. A solution was also provided to give cumulative infiltration per unit area of soil surface.

Hanks and Bowers (1962) used numerical methods to estimate the solution of equations of infiltration and moisture flow in layered soils. They were able to eliminate some of the restrictions of the Philip model, notably the need for an infinitely deep medium of uniform texture and an initial moisture content. They still required functional relationships between diffusivity and moisture content as well as matric potential and moisture content.

2.2.2. Moisture Redistribution

The numerical methods which became practical with the development of computers have enabled researchers to solve more complex mathematical relationships which more closely approximate real conditions. In particular, they have provided a means toward the solution of the complex equations describing unsaturated flow. Moisture movement under unsaturated conditions occurs in both the liquid and vapour phases, driven by any combination of gravitational, matric, osmotic, or thermal gradients. Hydraulic conductivity, diffusivity, and matric potential are functions of soil moisture content, and these relationships vary from one soil to another and are complicated further by hysteresis. Models describing these processes consider infiltration as a continuous portion of the moisture redistribution process.

The original description of unsaturated flow was developed by Richards (1931) who, using the Darcy equation

as a base, found that hydraulic conductivity was no longer a constant but now a specific function of matric potential. Since hysteresis was neglected, a more useful approach was to consider hydraulic conductivity as a function of soil moisture content.

Darcy: $q = -Ki$

where q = volume flux,

K = hydraulic conductivity,

i = hydraulic gradient.

Modified Richards: $q = -K(\theta)i$

where θ = moisture content.

Numerous attempts have been made to predict the hydraulic conductivity soil moisture relationship, $K(\theta)$. Childs and Collis-George (1950) developed an equation based on the function of matric potential and soil moisture (soil moisture characteristic curve) which can be measured in the laboratory. From their work arose the concept of diffusivity, $D(\theta)$ which relates the function of $K(\theta)$ to the slope of the soil moisture characteristic curve. Marshall (1958) and Millington and Quirk (1959) made improvements to the equation but all are based on capillary-tube concepts and are applicable only in some coarse textured soils where capillary forces predominate (Hillel, 1971). No method has yet been found to predict satisfactorily the function of hydraulic conductivity and soil moisture content from more easily-measurable soil properties and therefore it remains a characteristic that requires direct measurement for each

situation.

Klute (1965b) presented a method for direct measurement of K(θ) in the laboratory using disturbed soil. Field methods of measurement (minimally disturbed soil) have been presented by Rose et al. (1965) who used neutron probe measurements and laboratory-determined soil moisture characteristic curves to arrive at values for K(θ). Others (Nielsen et al., 1964; Van Bavel et al., 1968) used tensiometers for matric potential measurements and a neutron probe for determining soil moisture content. Nielsen et al. (1964) observed that field determinations of hydraulic conductivity required much less time and effort than did those obtained in the laboratory.

Freeze (1969) introduced a numerical modelling method that attempts to cover the majority of complexities involved in water movement into and through the unsaturated zone to the water table. He found that infiltration is controlled by several parameters including soil "type", rate and duration of precipitation and evapotranspiration, depth of ponding, depth to the water table, and the antecedent soil moisture conditions. The model underscored the importance of the functional relationships between matric potential, hydraulic conductivity, specific moisture capacity and moisture content in the redistribution of moisture in the unsaturated zone.

Several conclusions regarding groundwater recharge have been drawn by Freeze (1969) and Freeze and Banner (1970).

These include the following:

(i) water table rise occurs more frequently under wet antecedent soil moisture conditions

(ii) soils with a high moisture content over a range of tensions, a low specific moisture capacity, or a high hydraulic conductivity are most likely to transmit water to the water table, and

(iii) ponding at the soil surface will generally lead to recharge, especially in areas where the water table is shallow.

Perhaps the most fundamental conclusion is that knowledge of only saturated hydraulic conductivity and soil textural class will give erroneous estimates of recharge. In order to realistically evaluate soil moisture movement, the depth of the unsaturated zone and the functional relationships existing within it, must be measured.

2.3 GROUNDWATER

2.3.1 Groundwater Recharge and Discharge

Toth (1962) applied principles of fluid potential as presented by Hubbert (1940) to describe theoretically the groundwater flow systems within a small drainage basin on the Canadian Prairies. He defined a small basin as an area bounded by topographic highs, with its lowest areas being occupied by a body of impounded surface water or else by the outlet of a relatively low order stream. The basin would have similar physiographic conditions over its entire

surface. He suggested that the total area of a basin would not be more than several hundred square miles. Three major flow systems were classified by Toth: local, intermediate and regional. Local flow systems are brought about by minor and adjacent topographic highs and lows and they are usually superimposed on intermediate and regional systems. Recharge occurs in the upper topographic portions of a theoretical symmetrical basin while discharge occurs in the lower; the two are hypothetically separated by a midline (hinge line).

The process of recharge has been defined by Freeze and Cherry (1979) as the entry into the saturated zone of water made available at the water table surface together with the associated saturated flow away from the water table. Similarly they define the discharge process as the removal of water from the saturated zone across the water table surface, together with associated flow toward the water table within the saturated zone. Freeze and Cherry (1979) consider the processes of entry and exit of water into and out of the saturated zone as analogous to the entry and exit of water into and out of the unsaturated zone at the soil surface. Therefore they have defined infiltration as the entry into the soil of water made available at the soil surface together with associated flow away from the soil surface within the unsaturated zone. They define the term exfiltration, first used by Philip (1957f), as the removal of water from the soil across the soil surface, together with associated flow toward the surface within the

unsaturated zone.

Groundwater recharge and discharge rates are the result of an intimate association between the processes in both the unsaturated and the saturated zones. Freeze (1969) stated that in order for a water table to maintain a constant level in a recharge zone, a given amount of infiltration is required to balance the prevailing saturated flow rate. A water table rise is indicative of infiltration in excess of this amount. Similarly, a water table in a discharge zone requires a given amount of exfiltration to balance the prevailing saturated flow rate and a rise can bring about a decrease in exfiltration rate. Since infiltration and exfiltration are transient processes in nature, the water table is in constant fluctuation in response to characteristics of the atmosphere, the unsaturated zone, vegetation and the groundwater flow patterns. The depth of the water table often determines the relative intensities of the above influences. For example, Gardiner and Fireman (1958) found, using soil column experiments, that when the water table is within one metre of the soil surface, exfiltration rates are controlled by climatic factors. When the water table is below one metre, the rate is controlled by soil properties and water table depth. Freeze (1969) concluded that a dynamic equilibrium serves to limit the range of water table fluctuation.

2.3.2 Shallow Groundwater Flow

A perched water table, brought about by textural changes in the soil and subsoil stratigraphy, is most often implicated as the cause of discharge in dryland saline seep-affected areas. A perched water table is often a temporary, discontinuous zone of saturation above the true continuous water table (Freeze and Cherry, 1979). It generally promotes groundwater flow at shallow depths, increasing the probability of discharge within the proximity of the rootzone.

Several studies have found that saline seeps form where perched "aquifers" have encountered less permeable material downslope. Doering and Sandoval (1976) observed that saline seeps in North Dakota occurred where layers of lignite, scoria (burnt shale), or other highly permeable material were truncated at a shallow depth on a hillside. The truncating material, as well as the soil overlying the "aquifer", were of lower saturated hydraulic conductivity. Halvorson and Black (1974) found similar cases in Montana, as well as cases where flow occurred along contacts between layers of glacial till and more dense clay substrata. Studies on the Canadian Prairies (Christie, 1973; Oosterveld et al., 1978; Sommerfeldt and MacKay, 1982) have also shown that seep development results from similar layering conditions. Conducting layers are often thin, discontinuous, contorted, and scattered throughout the subsoil. This means that seeps can break out at several places along one hillslope and subsurface drainage may not be an effective

means of control. The conducting medium does not necessarily need to be highly permeable as a hydraulic conductivity of only one or two centimeters per year is all that is required to sustain a saline seep (Doering and Sandoval, 1976).

Recharge in saline seep-affected areas appears to be local, but some studies (Greenlee et al., 1968; Oosterveld et al., 1978) have suggested that flow systems of a more regional nature may be influencing some seepage areas. Generally, saline seep flow systems are complex due to the scattered, leaky nature of the perched "aquifers", coupled with the transient nature of recharge and the sustaining effect of larger flow systems. As a result, thorough studies of seep hydrology and reclamation procedures may become more complex than expected.

2.3.3. Groundwater Chemistry

The chemical evolution of groundwater is determined by the geochemistry and hydraulic conductivity of the material through which it passes, the amount of biological activity at the surface, rate of weathering and the amount and rate at which water moves from the soil surface to the water table. Therefore it is also indirectly influenced by the factors controlling recharge. The chemistry of prairie groundwater is most strongly influenced by the characteristics of the soil and shallow subsoil. Moran and Cherry (1977) provided a descriptive outline for the chemical changes that occur once precipitation waters enter

the soil-groundwater system. The explanation presented in this section is based in part on their discussions.

Glacial tills in southern Alberta are composed of material derived from the local bedrock and from distant sources. A till analysis by Pawluk and Bayrock (1969) showed that CaO ranges from 4 to 8 percent, and iron content ranges from 2 to 3.25 percent on the southern Alberta prairie. The CaO data are indicative of limestone and dolomite materials, while the iron data are indicative of pyrite. The textural characteristics of the tills generally reflect the textures of the bedrock, meaning that the tills of southern Alberta contain over 50 percent silt and clay-sized materials. The origin of sodium as the original dominant exchangeable cation on clay surfaces is not understood but it is believed to come from either sodic volcanic material and/or evaporites produced during periods of shallow seas in late Cretaceous time. A general statement on the composition of glacial tills is that they are fine-grained in texture and contain a mixed mineralogy which together provide a more favorable medium for plant growth than does the prairie bedrock.

Rainfall and snowmelt are, in non-industrialized areas, generally low in total dissolved solids and have a pH value of 5 to 6 (Freeze and Cherry, 1979). When precipitation waters enter the soil they encounter biologically-produced CO_2 in the soil air, and acidity (H+) in the soil water. Carbonation (dissolution of CO_2 in water) produces weak

carbonic acid which dissolves any limestone or dolomite present in the biologically active zone. If no groundwater discharge occurs, the carbonates of calcium and magnesium are eventually removed from the A and B horizons by leaching. Oxygen present in the soil air and dissolved in the soil water produces oxidation of pyrite, generating SO_4^{-2} and acidity. This increases the dissolution of carbonates. The ion suite of water passing from the soil to deeper subsoil becomes dominantly Ca^{+2}, Mg^{+2}, SO_4^{-2} and HCO_3^-.

Since recharge is a relatively rare event during the summer, pore water is concentrated by evapotranspiration and causes calcite and gypsum to precipitate in the C horizon. When recharge does occur, water flowing through the unsaturated zone will dissolve gypsum and carry it toward the water table. Since marine shale bedrock and some tills contain sodium as the dominant exchangeable cation, cation exchange results in sodium and sulfate ions dominating the ion suite of the water entering the groundwater system. Water chemistry studies of dryland saline seeps (Greenlee et al., 1968; Halvorson and Black, 1974; Oosterveld and Sommerfeldt, 1979) show that dominant ions at discharge sites are,in fact, sodium and sulfate. This lends support to the idea that the above processes are occurring in dryland saline seeps.

Gypsum is the key ingredient in the system. Its the rate of production depends upon rate of infiltration and recharge, the amount of native pyrite in the parent material

and the ease with which oxygen can diffuse or be carried to depth in the soil and subsoil. A reduction in the amount of exchangeable sodium present will mean an increase of Ca^{+2} and Mg^{+2} in the groundwater. Presence of complex mafic minerals can lead to the presence of chlorides in groundwater as well (Nielsen, 1973). Oosterveld and Sommerfeldt (1979) have observed nitrates in saline seep water that are in high enough amounts to be toxic to animals. Although no complete explanation of their source is known, nitrates could evolve from the bedrock materials. Power et al. (1974) have shown that geologic materials in the Ft. Union shales, Montana, contain exchangeable ammonium that is readily oxidized to nitrate. Nitrate nitrogen is frequently found in the upper 8 metres of the Ft. Union shales with concentrations below the rootzone of mixed prairie grasses as high as 30 to 40 ppm. The mineralization of organic nitrogen within the rootzone has been suggested as another possible nitrate source (Doering and Sandoval, 1976). Also, use of nitrogen fertilizers in agricultural management practices along the flow system, may contribute significantly to the nitrate content of discharge waters (Oosterveld and Sommerfeldt, 1979).

2.4 CULTURAL CONSIDERATIONS

Although the problem of dryland salinity is of recent origin, saline seeps and salinity have been occurring on the undisturbed prairies long before man settled there. Man's

activities on the prairie, however, have accelerated the spread of dryland salinity. Most activities alter the rate and distribution of recharge, and where seepage conditions have not prevailed for too long a period of time, a change in land management practices may be all that is required to correct the situation.

The activity that has been most often cited as the cause of new saline seeps is the practice of summerfallowing. Since small grains are the principle crops grown on the dryland prairies, crop success depends upon whether enough moisture can be stored in the soil each spring to supplement the precipitation during the growing season. Since greater supplies of soil moisture at seeding have consistently produced greater yields of wheat (Cole and Matthews, 1940), the crop-fallow system was adopted for small grain crop production in most dryland areas. Adequate moisture for crop production is highly probable if crops are grown in alternate years; however, in non-cropping years it produces water in excess of the soil moisture storage capacity, increasing the likelihood of recharge. Soils in the Lethbridge area, on the average, store approximately 25 percent of the 528 mm annual precipitation in a fallow cycle (Vander Pluym, 1978). The remainder of the water is lost to runoff, evapotranspiration, and deep percolation. Under a small-grain crop, evapotranspiration is approximately 175 mm of water over a 100 day growing season and since production is in alternate years, there are over 600 days in which

transpiration is not occurring (Oosterveld, 1978b). Native grasses would transpire moisture for about 300 days or 3 times as long, during the same two-year period. Most land during fallow years is frequently cultivated for weed control, and a mulch can be maintained to reduce surface evaporation. Therefore a crop-fallow system of management favors the retention of water deep in the rootzone and a more uniform moisture distribution throughout the soil profile. This situation increases the probability of soil moisture movement toward the water table. Since deep percolation will initially fill any available storage in the soil below the rootzone, it may take several years to fill an "aquifer" and generate a seep.

Other cultural practices which promote recharge include overgrazing of pasture land, excavations which lead to the retention of water on the soil surface, and the erection of structures or shelters which trap snow. Overgrazing, like summerfallowing, decreases transpiration by the reduction of leaf area. Cattle will pack the soil by hoof traffic, which along with removal of vegetation, increases surface runoff and ponding in depressions. The construction of ditches, roadways and water reservoirs serve to pond water, unless a means of drainage is provided. Windbreaks and fences will trap snow, resulting in ponding in the spring. Sommerfeldt and MacKay (1982) estimate that a caragana shelterbelt on a hillslope near Nobleford, Alberta allowed 3120 m^3 of excess water to enter the groundwater system from the melting of

snow which accumulated over the winter of 1974-75.

Cultural practices have been implicated by several studies (Ballantyne, 1963; Halvorson and Black, 1974; Doering and Sandoval, 1976) as causing saline seepage by altering the soil moisture relationships from their native state.

Upslope lands are especially sensitive to cultural practices, and they usually become recharge areas for downslope seeps. Recharge and discharge sites can often be less than a kilometre apart, however they are frequently far enough apart to cross a property line. The area of discharge from a developed seep is often smaller than that of the recharge site. As a result, a small quantity of water entering as recharge can converge to become a large quantity of water leaving the system at the discharge site. For example, if a recharge area is 20 ha for a discharge area of one hectare, one centimetre of water entering the system at the recharge site can produce discharge flow volumes as great as 2000 m^3. The time lag from a recharge event to its appearance at the site of the seep can range from hours to weeks, depending on the size of the flow system (Oosterveld, 1978b).

Changes in the land management practices in the recharge areas offer a solution if the recharge areas can be identified. Recharge does not occur uniformly over upland areas; Freeze and Cherry (1979) have concluded that recharge is areally variable. Depressions in upland areas should be filled or continuously cropped where feasible. Use of

summerfallowing should be judicious. In cases where it is neither economical nor practical to alter the management of recharge areas, consideration should be given to the removal of groundwater at or near the area of discharge. Where salt concentrations are not excessively high, a deep-rooted crop or strip of perennials could effectively intercept groundwater flow by transpiration. Oosterveld (1978b) cautions that this method is a temporary solution and subject to physiological and climatic factors. The use of artificial drainage, such as subsurface drains, to intercept discharge flow has been successful in gaining quick hydrological control of saline seeps (Doering and Sandoval, 1976). The extent of control, however, is governed by the cost (Oosterveld, 1978b). Suitable outlets for the drained water must also be provided.

Where saline seeps are encroaching or have been in progress for a short period of time, changes in land management practices may be sufficient for reclamation. If saline seeps have been in progress for too many years, salt removal from the soil must be accomplished in addition to the removal of the discharging groundwater. Natural leaching of salts from a highly saline area can take several decades. The need for early identification of saline seeps and rapid implementation of land management changes to promote reclamation cannot be underestimated in importance.

III. METHODS OF MEASURING SOIL SALINITY

3.1 LABORATORY METHODS

The term soluble salts, as used in soil science refers to the inorganic soil constituents that are appreciably soluble in water (Bower and Wilcox, 1965). An approximate method for their quantification was presented by Whitney and Means (1897), whereby the electrical resistance of a saturated soil paste was measured. The general laboratory procedures used in more recent times, however, involve the preparation of an extract (a solution separated from a soil water mixture) and the subsequent measurement of the concentration of dissolved electrolytes within the extract.

3.1.1 Extract Preparation

The choice of a method for extract preparation depends upon the purpose for which the determination is intended and the accuracy desired. A general rule is that the higher the water content of a soil solution, the easier the process of removing that solution from the soil, since separation can be accomplished by the settling of the solid component, or filtering, without the need for a means of suction. If the purpose of the measurement, however, is to relate salt concentration to plant growth, extracts taken from soil-water mixtures of high water contents are not representative of the soil solutions in which plants grow.

Therefore, soil-water mixtures should be at lower water contents, similar to those at which plants normally grow (Bower and Wilcox, 1965). Since soils vary in their ability to retain water, and salt concentration can change with varying water content, an ideal extract would be one that is obtained from a sample at field water content. This, however, becomes time consuming requiring a large number of samples and therefore is impractical for routine laboratory use. The United States Salinity Laboratory Staff (1954) therefore adopted the technique of making a saturated soil paste, relatively reproduceable by defineable characteristics, from which an extract can be obtained. This is known as the saturation extract method and it has become widely accepted as the standard method by which extracts can be obtained for electrolytic concentration measurements, and the subsequent determination of soil salinity as it affects plant growth. Other water-soil ratios, such as 5:1 (United States Salinity Laboratory Staff, 1954) or 10:1 (Marshall and Palmer, 1938) can be useful in determining soil salinity for purposes other than its relation to plant growth.

3.1.2 Measurement of Electrolytic Concentration

Measurement of the electrolytic concentration of solutions was at one time given in terms of total dissolved solids. This was accomplished by evaporating a known volume of solution and weighing the residual salts. This method was primarily used for the assessment of salinity in irrigation

and return flow waters. Hygroscopic water present in the residual salts made the measurement strongly dependent upon the method of drying, however (Bohn et al., 1979).

A more widely-adopted method is the determination of the electrolytic concentration of a soluble salt solution by measuring its electrical conductivity. When a known electrical potential is applied across a given distance through a solution, or any conducting medium, current flow becomes proportional to the resistance of the medium. The resistance is inversely proportional to electrolytic concentration and can be easily measured with a resistance bridge. Since conductivity is the reciprocal of resistance, it has been chosen in order that the proportionality relationship becomes direct. To measure conductivity, electrodes of a constant geometry must be placed parallel to each other in the electrolytic solution and the same spacing used from one solution to another. The electrode geometry determines the cell constant, which can be obtained by calibration with potassium chloride solutions of known concentrations. Procedures for calibration are given by Bower and Wilcox (1965). Electrical conductivity values are expressed in terms of Siemens/centimetre or milliSiemens/centimetre (mS/cm) where Siemens are numerically equal to mhos.

The work of the United States Salinity Laboratory Staff (1954) provided chemical definitions regarding types of salt-affected soils (Table 3.1) as well as plant response

standards as related to saturation extract electrical conductivity (Table 3.2). Saturation extract electrical conductivity has also been empirically related to total salt, or total dissolved salt (TDS) in the case of water chemistry, by the relationship (United States Salinity Laboratory Staff, 1954)

$$\text{TDS (mg/L)} = 640 \text{ ECe (mS/cm)} \tag{3.1}$$

where ECe represents the electrical conductivity measured from a saturated extract at 25 degrees C. Chang (personal communication) has found that relationships between TDS and ECe varied in sulfate-dominated extracts. Over a range of electrical conductivities from 0 to 2 mS/cm the equation he derived was

$$\text{TDS (mg/L)} = 726 \text{ ECe} \quad (r=0.998) \tag{3.2}$$

while for a range of ECe values from 2 to 16 mS/cm it became

$$\text{TDS (mg/L)} = 965 \text{ ECe} - 310 \quad (r=0.992) \tag{3.3}$$

He also found a curvilinear relationship for the range of ECe values from 0-16 mS/cm where

$$\text{TDS (mg/L)} = 6.88(\text{ECe})^2 + 861(\text{ECe}) \quad (r=0.998) \tag{3.4}$$

Table 3.1 Traditional classifications of salt-affected soils.

Normal Soils	Saline Soils	Sodic Soils	Saline-Sodic Soils
EC < 4 mS/cm	EC > 4 mS/cm	EC < 4 mS/cm	EC > 4 mS/cm
ESP < 15%	ESP < 15%	ESP > 15%	ESP > 15%

*Terminology Committee, Glossary of Soil Science Terms. Soil Science Society of America, Madison, Wisconsin, 1973.

Table 3.2

Response of plants associated with different ranges of electrical conductivity of saturation extracts of soils. Reprinted from Bower and Wilcox, 1965.

Electrical Conductivity of Saturation Extract, mS/cm at 25° C.	Plant Response
0-2	Salinity effects usually negligible
2-4	Yield of very salt-sensitive crops may be restricted
4-8	Yield of salt-sensitive crops restricted
8-16	Only salt-tolerant crops yield satisfactorily
> 16	Only a few very salt-tolerant crops yield satisfactorily

3.2 FIELD METHODS

Field assessments of soil salinity have traditionally involved soil sampling and subsequent laboratory determination of the salt content by the saturated paste electrical conductivity method (Oosterveld, 1978b). Saline seeps and encroaching saline seeps can only be properly delineated and identified once the laboratory analyses are complete. The making of accurate maps of large areas involved the collection and analysis of a large number of samples, a process which becomes time-consuming and expensive for routine surveys if laboratory techniques are used. To examine dryland areas for saline seep activities adequately, surveys of large areas are required at some regular interval of time. A need exists, therefore, for a survey technique which requires a relatively low investment of money, manpower, and time, and can be easily performed at regular time intervals.

Salinity sensors can be implanted into the soil at desired depths for in situ salt measurements. The sensors generally consist of electrodes within a ceramic medium, which reaches equilibrium with the soil solution. Electrical conductivity can be read quickly and directly from a resistance bridge. Calibration is achieved by initially taking measurements with the sensor in solutions of known electrical conductivity. Sensors such as these are useful for the continuous monitoring of salt movement at a given location. Although they provide information rapidly once

installed, they are expensive and generally impractical for salinity survey activities.

Rhoades and Ingvalson (1971) presented a method whereby soil salinity could be quickly assessed by use of the electrical resistance of the undisturbed soil-water system by measurements with a four-electrode array. Halvorson and Rhoades (1974) extended this method into a means of identifying potential saline seep areas. Halvorson and Rhoades (1976) found the four-electrode method successful for detecting and delineating saline seeps and encroaching saline seeps. The method has been found to be rapid, with a relatively low cost for equipment and manpower, and it can produce results in the field with a minimum of laboratory analysis. Halvorson and Rhoades (1976) concluded that the four-electrode method can be a useful tool for field surveys of large areas, and it can provide information rapidly for planning remedial measures to control the development of a saline seep. However, most studies using the four-electrode method have been performed under conditions of relatively uniform moisture contents, both areally and within the soil profile. It has not been thoroughly studied under conditions where moisture contents, temperature, and texture vary, as would be the case if periodic seasonal surveys were to be performed on the prairies of southern Alberta.

IV. ELECTRICAL RESISTANCE SURVEYING

Electrical resistance measurements are one of several geophysical techniques used to gain information about subsurface geological characteristics, using a minimum of borehole information. Some electrical methods require introduction of direct or low-frequency alternating current into the ground by means of electrodes. The form and density of current flow measured at the surface is partially dependent upon the distribution of resistivity in the subsurface material. The resistivity of a material is defined as the resistance of a cylinder of that material with a unit cross-sectional area and a unit length (Dobrin, 1976). In direct application of current, by electrodes, the property measured is the potential gradient, although it may be given as a corresponding resistance by the measuring instrument.

Current can also be generated in the ground by induction from low or high-frequency electromagnetic wave energy emitted through a coil not in direct contact with the ground. Corresponding waves propogated in the ground, are alternated at a rate that is dependent upon both the wave frequency and the electrical properties of the material through which they pass. Conducting materials will have alternating electrical currents induced in them, and these are measured by an above-ground detecting coil. Induction measurements are used in both aircraft reconnaissance and surveys by foot. They have also been used in surveys of

saline soil (Cameron, 1980).

Since most minerals are good insulators, electrical conduction is mainly by electrolytes in the interstitial water. Therefore resistance depends upon the porosity and pore geometry of the material, its degree of saturation, and the concentration of dissolved electrolytes. Metallic sulfide ores, and some clay minerals which have sodium dominating their exchange complexes will themselves contribute significantly to conduction and are consequently exceptions to the previous statement. It is apparent, therefore, that strata can produce a wide range of resistivities, certainly from one rock type to another but also within a given formation. As a result, it is difficult to correlate lithology with resistance, per se, but generalities can be drawn. For example a trend of increasing resistance exists from clay to sands and gravels, to limestone to, finally, crystalline rocks. Dryness, however, can increase resistance by an order of magnitude in any one rock type (Griffiths & King, 1965).

4.1 FOUR-ELECTRODE MEASUREMENTS

Consider a condition where current is directly introduced into the ground by means of a source electrode, and exits from the ground at a sink (negative) electrode. The depth below the surface through which the current flows is directly proportional to electrode separation. Therefore, two electrodes two metres apart will produce a current flow

in the soil to a depth of two metres. A theoretical explanation is provided by Griffiths and King (1965). When two or more layers of differing resistivity exist, the proportionality is no longer exact as current flow lines are refracted across the boundary.

To measure potential gradient in a two-electrode system, an additional pair of electrodes can be inserted between the current pair. The value measured is the average potential gradient between the potential electrodes and, although measured at the surface, it is influenced by the flow lines beneath the surface. Resolving power increases as the spacing between the potential electrodes decreases, and accuracy is reduced due to the decreasing distance over which the potential gradient is measured.

There are three configurations of electrodes that are popular in geophysical surveying. The Wenner configuration has an equidistant spacing between the current and potential electrodes. It offers advantages in ease of operation and interpretation. The Schlumberger arrangement is similar to the Wenner but with a closer spacing of the potential electrodes, in relation to the current pair. It is suitable for work where high resolution is required. The Lee Partition spacing, a configuration of four equidistant electrodes with a fifth at the midpoint, is suitable for measurements where surface material is non-homogeneous or contains several lateral anomalies such as rock outcrops or water. Equations to calculate resistivities for each, and

their theoretical derivations are provided by Griffiths and King (1965).

Electrical resistance surveys are usually carried out across an area by means of either a traverse or a grid. Depth of a layer or to a layer is determined by a set of successive measurements at one site or grid point. Each new measurement has a larger electrode spacing than the last, therefore the resistivity of the material is determined to an increasing depth. Sharp changes in resistivity indicate the presence of a zone of differing conductivity. Depth to groundwater can be determined in this manner, as can the differentiation of saline groundwater from non-saline groundwater. Isolated bodies of ores have been located this way, as well. Cook & Van Nostrand (1954) have presented data interpretation for ores located in limestone sinks. Data can be presented as curves of resistivity versus depth, or a map of isolines delineating resistivities. The Wenner array, or "four-electrode" array, is often used for depth determinations of conducting bodies because of ease of use in the field and the large data base previously acquired.

Survey work with electrical resistance is useful where the changes in the resistance properties of the material are not too complex. Even when this is the case the confidence in reproducibility of the numerical values applies only over a limited range of problems, and survey data should be supplemented with some borehole information.

4.2 APPLICATION TO MEASUREMENT OF SOIL PROPERTIES

In Soil Science, electrical resistance has been tested as a method of measuring soil moisture in situ since the turn of the century (Whitney et al., 1897). Early investigations involved measurement of soil resistance between two electrodes with little success. One of the causes of early failures was the presence of contact resistance between the electrode and the soil. Using four electrodes eliminated this problem (McCorkel, 1931) and Edlefson & Anderson (1941) gave theoretical proof and experimental evidence to support this. Kirkham and Taylor (1949) introduced the Wenner array for determination of soil moisture content; however, they concluded that soil salinity had too great an influence for moisture contents to be accurately measured.

Shea and Luthin (1961) investigated the possibility of using the Wenner array, or four-electrode method, for salinity assessment. They did not intend it to replace the saturation extract technique, but to give a nondestructive, direct estimate of the quantity of salts in the field. Their tests were, however, conducted in a cubic tank, 1.2 m per side, with electrodes buried to desired depths. In this way, salts and moisture contents could be controlled. They found that soil salt content could be measured by a four-electrode method with accuracy comparable to the saturation extract method, but lack of moisture and temperature control could lead to considerable error. They concluded that the method

showed promise but more study was needed to determine the reliability of the method.

Rhoades and Ingvalson (1971) used the Wenner method to measure salt contents in field plots which were adjusted to various levels of salinity. Electrodes were inserted 2.5 cm into the surface and the inter-electrode spacing controlled for measuring to depths of 30, 60, 90 and 120 cm. Their results showed excellent correlation with electrical conductivities of saturation extracts of samples taken at the same locations. Halvorson and Rhoades (1974) used the four-electrode method to identify potential saline seeps and assess soil salinity, and Halvorson and Rhoades (1976) extended the method to field mapping of soil electrical conductivity in order to delineate dryland saline seeps. Rhoades et al. (1976) investigated several important parameters that affect measurement of salinity. These included tortuosity, water content, and surface conductance. Halvorson et al. (1977) studied different methods of calibration and also the influence of soils of different textural classes and parent materials on relationships between four-electrode measurements and electrical conductivities of saturation extracts. Rhoades and Halvorson (1977) produced a manual on detection and mapping of saline seeps, and included calibration methods and calibration curves for representative soils of the Northern Great Plains. In all cases moisture variability was lessened by measuring in the early spring or immediately following

irrigation. Oosterveld et al. (1978) and Read and Cameron (1979) have used the four-electrode technique to delineate saline areas on the Canadian prairies. Nadler (1980) has further investigated the relationship between inter-electrode spacing and depth of measurement in soils. Nadler and Frenkel (1980) studied the significance of surface conductance at low salinities and presented a method for its calculation.

4.2.1 Theory of Operation in Soils

The theory of electrical resistivity of the Wenner array has been well documented (Griffiths and King, 1965; Shea and Luthin, 1961). Briefly, if a known current originates from a point source and exits by a point sink, Ohm's law can be used to calculate the potential drop between the inner electrodes. Resistance is given by

$$R = \Delta V/I \qquad (4.1)$$

where "R" is resistance (ohms), "I" is current (amperes) and "ΔV" is the potential difference (volts). If the current is carried with parallel lines of flow over a cross-sectional area, then the resistivity of the medium becomes

$$p = R\ A/a \qquad (4.2)$$

where "p" is resistivity (ohms·cm), "A" is cross-sectional area (cm^2) and "a" is the distance between potential electrodes (cm). Griffiths and King (1965) derived resistivity in terms of "R" for a homogeneous and infinite medium as

$$p = 4\pi a R \tag{4.3}$$

Since in practice, the earth's surface presents a limit to the medium, resistivity must be reduced accordingly. This boundary condition is represented by a factor "n" where

$$p = 4\pi a R/n \tag{4.4}$$

Wenner calculated "n" for his electrode configuration to be

$$n = 1 + [2/\sqrt{(1+4(b/a)^2)}] - [1/\sqrt{(1+(b/a)^2)}] \tag{4.5}$$

where "b" is the depth of the electrode below the surface. If "b" is small in relation to "a", "n" approaches 2 and equation 4.4 becomes

$$p = 2\pi a R \tag{4.6}$$

If "b" is large compared to "a", n approaches 1 and equation 4.4 becomes

$$p = 4\pi a R \tag{4.7}$$

For the purpose of measuring soil salinity "a" is considered large in relation to "b", therefore resistivity can be calculated from the measured R value by equation 4.6. This means that care must be taken that the probes only enter the soil deep enough to support their weight, or else significant deviations from equation 4.6 can develop.

Rhoades and Ingvalson (1971) converted resistance to an electrical conductivity in order to correct for geometrical differences in current flow as the inter-electrode spacing was increased from 30 to 120 cm. As a result, measured values are now independent of inter-electrode spacing. Rhoades and Ingvalson (1971) termed this value as an "apparent" electrical conductivity because the heterogeneity of most soil profiles results in it having a different value from electrical conductivity measured by the saturation extract method. Their equation of conversion is given as

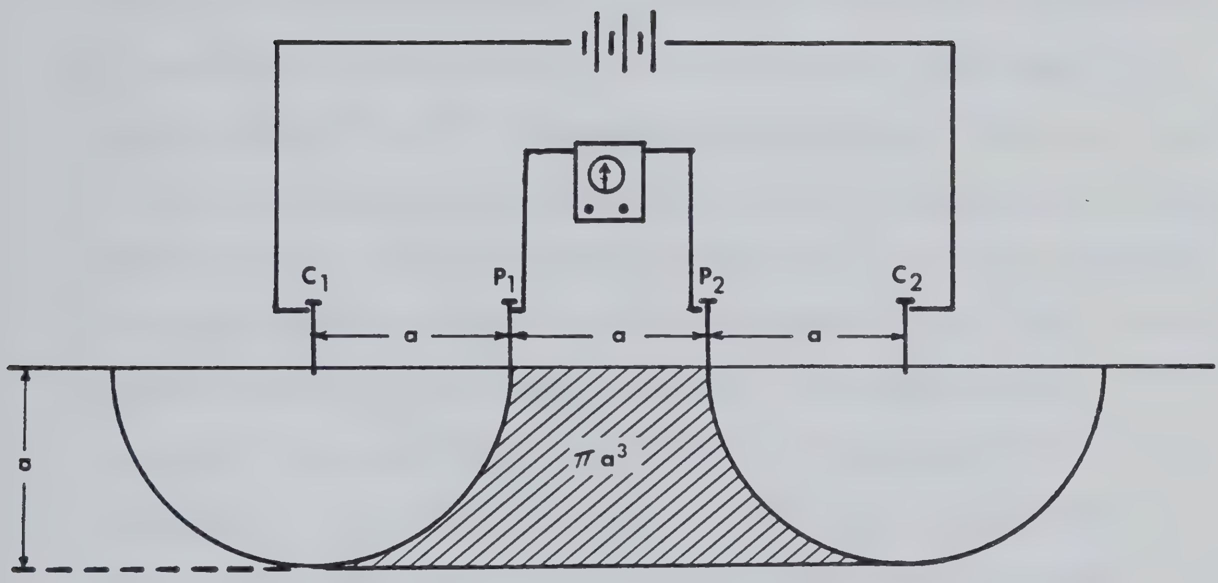
$$ECa = 1000/(2\pi a R) \tag{4.8}$$

where "ECa" is apparent electrical conductivity expressed as mS/cm to be consistent with the common unit of electrical conductivity measurement in soils.

Voltage applied to the four-electrode system can be either alternating or direct current. Alternating current is preferred since direct current can produce ion polarization, as well as being influenced by natural currents generated in

the earth. Since both natural currents and polarization effects are uni-directional they can be eliminated by use of alternating current. Low frequencies are preferred since ground inductance and capacitance can complicate current flow at frequencies above a few tens of cycles per second (Griffiths and King, 1965). Generation of direct current is more practical in field conditions, where batteries often provide the power source; therefore, it is pulsed to low frequency alternating current by a vibrator included in the measuring instrument. Some field meters use a hand cranked generator as a power source and therefore produce alternating current directly. Once power has been applied to the current electrodes, potential in another circuit is balanced against the potential difference across the inner electrodes, with the difference being reflected by a null meter (galvanometer). Potential on this circuit can be adjusted to equal the potential across the inner electrodes, and this value is given as the resistance "R" by the meter. Therefore, most meters used in four electrode measurements have a power source that either generates or else converts to alternating current, a galvanometer to indicate resistance, and also an ammeter to detect any variations in current in order that they can be quickly corrected.

A diagram of the geometrical configuration of the Wenner array is provided as Figure 4.1. Rhoades (1975) has calculated the measured volume of a homogeneous material to be approximately equal to πa^3, shown as the hatched area in



a = interelectrode spacing

P_1, P_2 = potential electrodes

C_1, C_2 = current electrodes

Figure 4.1 Schematic diagram of four-electrode apparatus (Rhoades and Halvorson, 1977).

Figure 4.1. This means that small changes in the interelectrode spacing produce large changes in the volume of material that is measured, and therefore a means is provided whereby the bulk volume of measurement can be controlled.

When an electrical potential is applied to a soil-water system, ions from soluble electrolytes are accelerated to the pole of opposite charge. Ion flow is enhanced by exchangeable cations which are mobile to various degrees in an electrical field. This is known as surface conductance. Resistance to flow is strongly influenced by the number and size of interconnecting pores as well as the amount of pore water present. Viscous forces present in the soil solution allow a terminal velocity to be attained by the ions, known as ion mobility, and since viscosity is temperature dependent, ion mobility decreases with decreasing temperature. Ion concentration also influences viscosity, with ion mobility being reduced when the concentration exceeds a limit. Below this limit, increasing concentration will enhance current flow. It is therefore evident that the resistance of a soil-water system depends upon its water content, pore geometry, temperature, surface conductance, and electrolytic concentration.

Rhoades et al. (1976) have developed an equation to describe the above relationships, and it is given in the form of apparent electrical conductivity, as calculated from measured resistance according to equation 4.9. It shows that

$$ECa = (ECw\ \theta\ T) + ECs \tag{4.9}$$

where θ is volumetric water content, T is a transmission coefficient related to both θ and pore geometry, ECw is electrical conductivity of the soil solution, and ECs is surface conductance, or the electrical conductivity of the solid soil matrix. Since ECs and T are properties of the solid soil component, they are unique to a given soil. Rhoades et al. (1976) determined that T was linearly related to θ, and assumed that the ECs contribution was small in saline soils and constant over a range of salinities. Therefore, for a given soil, ECa can be empirically related to ECw and θ. If the water content is nearly uniform both areally and throughout the profile, and relatively reproduceable (such as field capacity), Rhoades and Halvorson (1977) assumed that ECa could be solely dependent upon ECw. In turn, ECw is uniquely related to the electrical conductivity determined by the saturation extract method (ECe). The resulting empirical relationship between ECa and ECe has been presented by Rhoades and Halvorson (1977) as

$$ECa = A\ ECe + B \tag{4.10}$$

To account for temperature difference, since ECe is measured at 25°C, a correction factor, Ft, provided by the U.S. Salinity Laboratory Staff (1954) was incorporated in the determination of ECa by Rhoades and Halvorson (1977) as

$$ECa = A\ ECe\ Ft + B \tag{4.11}$$

They recommended a calibration procedure for a given soil by measurements of electrical conductivity by both the four-electrode and the saturation extract methods over a range of salinities at a reference water content. The values of ECe and ECa can then be plotted on a graph and the constants A and B determined by linear regression.

Rhoades and Halvorson (1977) have quantified the ECa versus ECe relationships for soils of typical textural classes found in Montana and North Dakota. They have recommended use of their data for soils of similar textures and water-holding capacities in the northern Great Plains. They have also provided a method for using four-electrode measurements to delineate saline seeps.

Since ECa is a variable describing a bulk soil electrical conductivity, the four-electrode method implies that the interval of measurement always extends from the surface to the desired depth. Rhoades and Halvorson (1977) determined that the electrical conductivity at a discrete soil depth interval can be determined, assuming that the depth of measurement is equal to the interelectrode spacing (a), and that the electrical resistances of a stack of soil layers behaves like resistors in parallel. The discrete depth electrical conductivity, ECx, can be derived from a series of ECa values for increasing depth intervals by the equation

$$ECx = EC_{a_i - a_{i-1}} = [(EC_{a_i} \cdot a_i) - (EC_{a_{i-1}} \cdot a_{i-1})]/(a_i - a_{i-1}) \quad (4.12)$$

where a_i represents the interelectrode spacing and a_{i-1} represents the previous interelectrode spacing. Determination of ECx provides a means whereby a discrete soil depth interval can be assessed for salinity, but for soils with marked horizontal variations in texture or salinity the method does not apply.

The four-electrode method provides a method for rapid, inexpensive soil salinity measurements directly in the field and has been tested in a variety of soil conditions in Montana and North Dakota. There are, however, some factors, such as field moisture content and texture, which can theoretically limit its general use. In addition, it has not been tested under conditions of high temperature or moisture gradients within the soil profile, or under the soil environments found in Alberta. There is a need to determine how limiting the restricting parameters are in regards to the application of the four-electrode method to a specific purpose. Also there is a need to determine more accurately the general range of operating conditions under which the method can be used with confidence.

This study examines the four-electrode method under conditions of changing soil temperature and moisture conditions and compares its suitability in delineating saline seeps by means of salinity contour maps against those developed by sampling and laboratory analyses. Also this

study will attempt to determine the usefulness of the four electrode method in monitoring soil salinity fluctuations at given locations throughout the growing season. It is hoped that information from these investigations will contribute to the determination of the purposes for which the four-electrode method is best suited.

V. SITE DESCRIPTION

The field measurements for the study were carried out in two general locations: a closed drainage basin immediately south of the village of Nobleford, Alberta (Fig. 5.1) and at the site of the Agriculture Canada Research Station at Lethbridge, Alberta.

5.1 NOBLEFORD SITES

The closed basin at Nobleford forms a topographic dome covering about 650 ha, within which is contained a depressional basin with no drainage outlet (Sommerfeldt and MacKay, 1982). The difference in elevation between the upland and the lowland is over 30 m. Bedrock geology consists of the St. Mary's River formation to the north and west, and the Bearpaw formation to the south and east. Between these formations is a narrow band of the Blood Reserve formation of non-marine and marine sandstones. Bedrock was observed by Sommerfeldt and MacKay (1982) to be contorted and fractured in the area north and west of the depression. The depth to bedrock ranges from one metre in the upland to seven metres in the lowland (Sommerfeldt, 1973). Surficial material in the lowland is mainly fine to medium textured, overlying fine-textured subsoil with inclusions of thin layers of sand. Most of the remaining material within the basin is coarse to medium textured, overlying coarse textured subsoil (Sommerfeldt and MacKay, 1982). A kame is located at the northeast edge of the

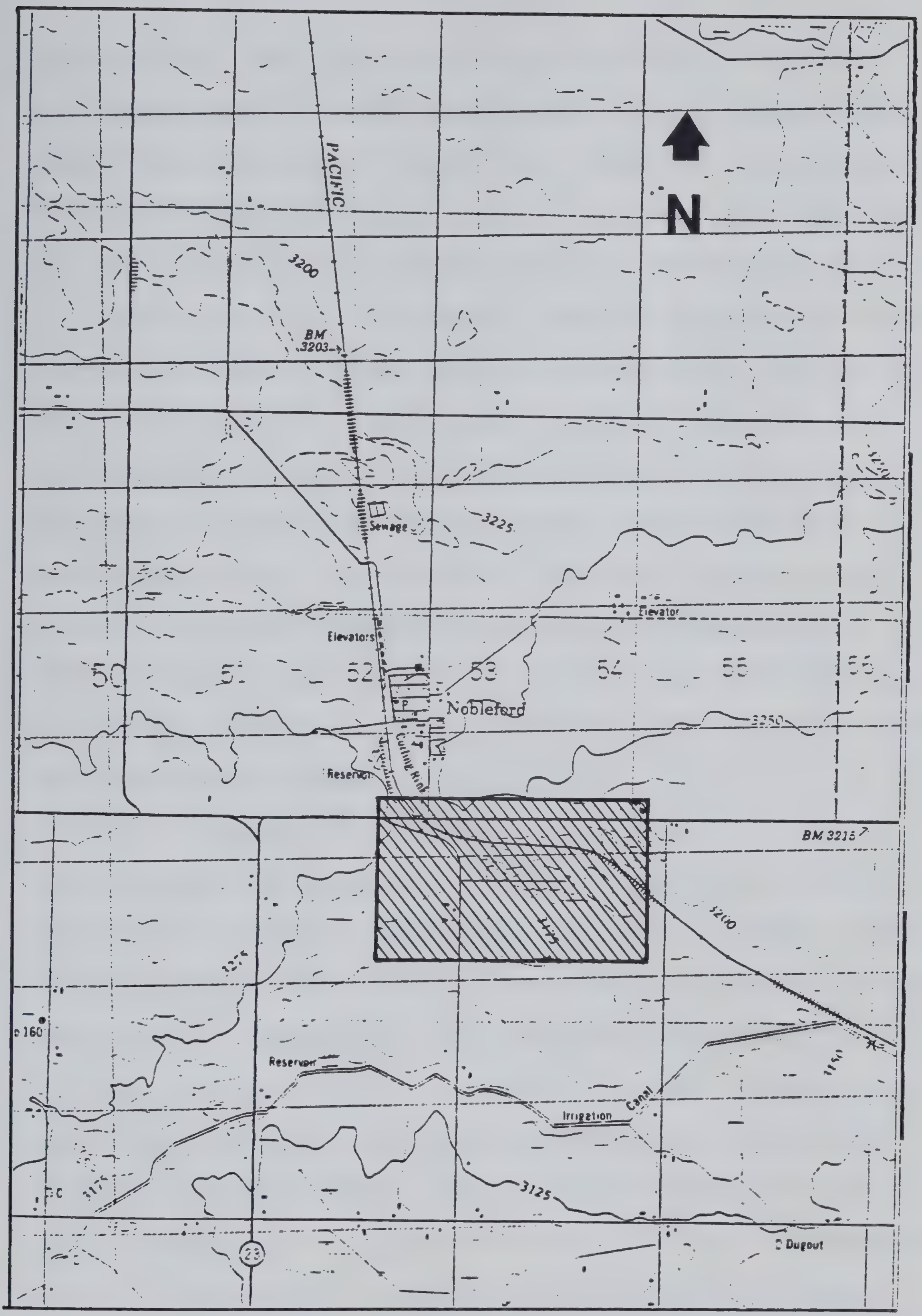


Figure 5.1 Nobleford study area.

depressional area and coarse-textured material extends southward from it across the lowland, dividing the lowest areas into two parts. The dominant soils of the area have been mapped as Orthic Dark Brown Chernozems developed in till or fine-textured lacustrine veneer (Kocaoglu, 1977).

Since the basin is closed, there is no external outlet for surface water, which collects almost every year in one or both of the two lowest areas. Roadside ditches and a railway grade across the northern slope of the depression also serve to collect surface water. Ponding has been serious enough in the lowland to delay or restrict the planting of cereal grains (Oosterveld and Sommerfeldt, 1979). Soils of the lowland are affected by waterlogging and salinity, and saline seeps are breaking out along the north and west basal slopes of the depression.

The climate of the region is continental but the proximity of the mountains to the area provides somewhat of a moderating effect. Lethbridge, the closest major weather station, enjoys the warmest winter temperatures and highest mean annual temperature of any weather station on the Canadian Prairies and yet the maximum summer temperatures are slightly cooler than many locations in the southern Canadian prairies (Hobbs, 1977). Long term mean annual precipitation in the Nobleford basin is 352 mm. Evaporation from a class A pan in Lethbridge, based on a nine-year average, is 1302 mm (Hobbs, 1977). Mean evaporation exceeds precipitation by 200 mm per month for May, June, July and

August.

The land of the basin was initially settled in 1904 and the practice of crop-summerfallow farming was used for moisture conservation. By 1920, wind erosion was becoming a problem and measures such as strip cropping and the planting of shelterbelts were undertaken in the area. The crop-summerfallow system was still in practice in the northern upland part of the basin in 1979. Evidence of a water table rise started about 1950 when areas of lush vegetation growth appeared on the side slopes (Oosterveld and Sommerfeldt, 1979). Management practices were changed in the lowland during the 1960's to annual cropping and planting of permanent grass in the most seriously affected areas. Management in the northern uplands was controlled by a different owner, however. As the problem continued, research personnel from Agriculture Canada were invited to study methods of control.

A hydrological study by Sommerfeldt and MacKay (1982) has determined that the groundwater flow systems of the area are complex, with most of the flow affecting the soils of the basin being local rather than regional. Potential sources of recharge were identified as deep percolation from summerfallow fields in the upland, and temporary bodies of trapped surface water caused by the presence of the road, railway and village reservoirs. Drifted snow which accumulated along a caragana shelterbelt on the northwest slope of the depression was also implicated as a potential

recharge source. The bodies of impounded water were found in areas of bedrock contortion, where fracturing could be expected. They were also above and in close proximity to three sites where upward piezometric pressure was observed. The saline seeps were believed to be caused by the restriction of subsurface drainage by both the break in slope and the change to finer-textured soils in the lowland.

A reclamation program was implemented in 1977 whereby interceptor subsurface drains were installed in the seep-affected area at NW-34-23-10-W4. At this location, evidence of a water table rise began about 1950, and in 1975, an open excavation had been constructed to measure flow rates. The subsurface drainage outlet was a dugout in SW-34-23-10-W4. Surface water was drained by means of ditching, which also outlet into the dugout. The collected water would then be pumped back onto cropland as irrigation (Oosterveld, 1978a; Oosterveld and Sommerfeldt, 1979). An excessively wet spring in 1978 resulted in overflow of the dugout and inundation of several acres of lowland until July of that year. The interceptor drains provided insufficient hydrologic control of the saline seeps, and more drainline was installed in a loop around the open excavation. The excavation was then partially filled with a gravel envelope, and then completely backfilled later that year. The complete drainage project is illustrated in Figure 5.2.

Samples of subsurface water collected from the drain outlet showed that dominant ions are Na^+, SO_4^{-2} and NO_3^-

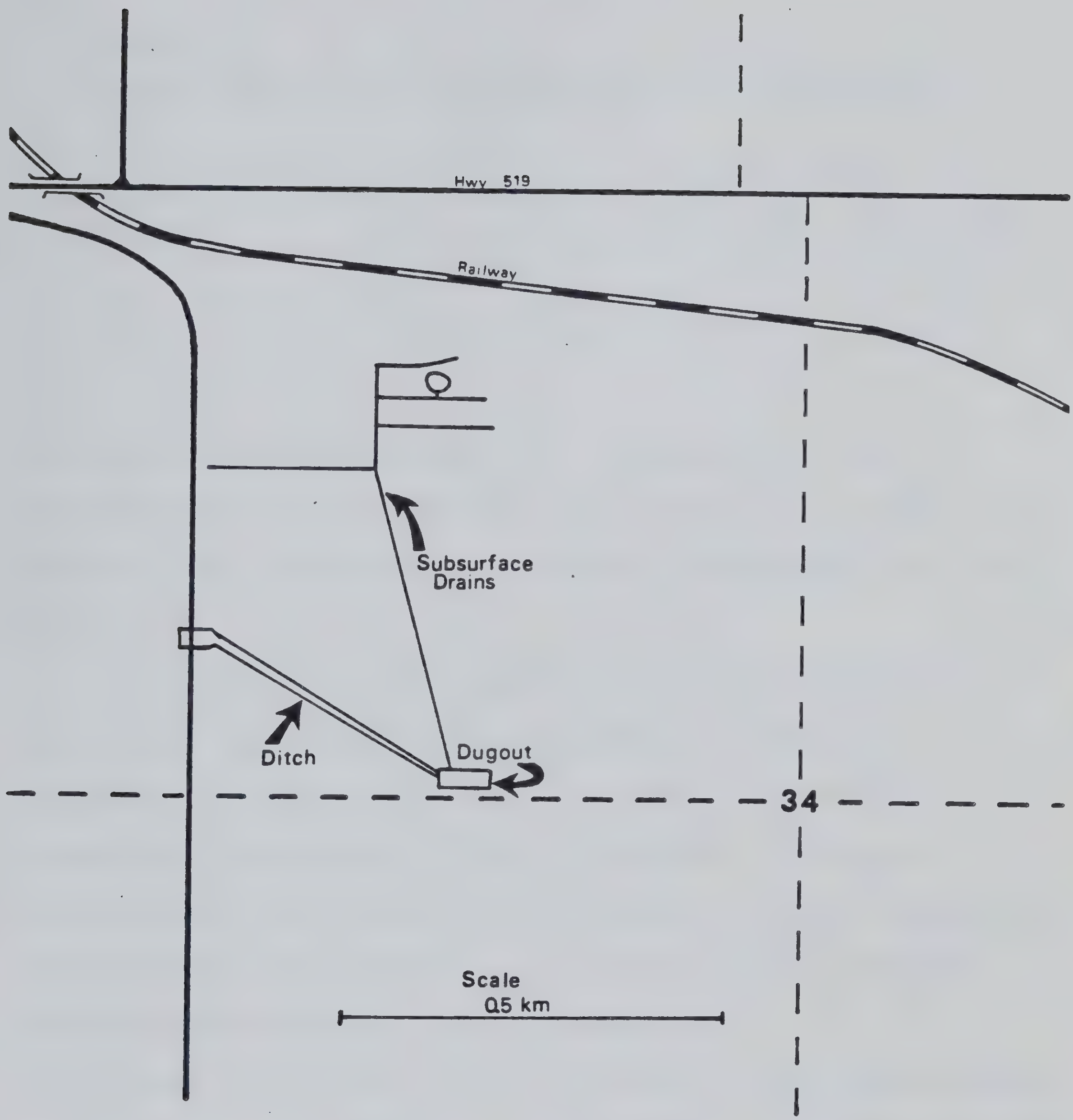


Figure 5.2 Surface and subsurface drainage at Nobleford study area.

(Oosterveld and Sommerfeldt, 1979). The sample chemical composition is provided in Table 5.1.

Table 5.1

Chemical composition of subsurface drainwater at the Nobleford basin. Reprinted from Oosterveld and Sommerfeldt, 1979.

Ec mS/cm	S.A.R.	pH	Na^+ meq/L	Ca^{+2} + Mg^{+2} meq/L	SO_4^{-2} meq/L	HCO_3^- meq/L	Cl^- meq/L	NO_3^- mg/L
9.3	17.1	7.7	85	49	104	16	3.9	82

The presence of high amounts of nitrates have been attributed to deep percolation of fertilizer nitrogen from agricultural activity in the upland (Sommerfeldt and MacKay, 1982).

Instruments for the measurement of meteorological parameters have been located in NW-34-23-10-W4 and precipitation data since 1921 has been presented by Sommerfeldt and MacKay (1982). Collection instruments consist of a rain gauge, a snow gauge, a class A evaporation pan, a water table recorder, air and soil (10 cm depth) temperature recorders, and an anemometer.

Three sites were initially chosen in 1979 for periodic salinity surveys. One site was chosen on the field where the interceptor drains had been placed. This site will be referred to as Drainfield. Another site was chosen on NE-33-23-10-W4, the field immediately west of Drainfield. At this location, an established saline seep was observed to be

expanding upslope, and the upslope portion of the seep was to be surveyed. This field will be referred to as Westfield. The third site, Eastfield was located on NE-34-23-10-W4. Like the Westfield site, an established seep in this field was expanding and the upslope position was to be surveyed. Although the principal purpose of site selection was to provide saline seep-affected soils that could be used for comparison of the four-electrode method with the saturation extract method for salinity evaluation, sites were selected that could possibly provide additional information that could be interpreted by the four-electrode method. The purpose of selecting the Drainfield site was to determine if any change in soil salinity could be detected, now that subsurface drains had been placed. The purpose of selecting the locations of the Westfield site and the Eastfield site was, in addition to delineating saline soils from less saline soils, to locate points of groundwater discharge.

In 1980, an additional site was chosen on NE-33-23-10-W4. This site, Hedgefield, was selected where an encroaching saline seep was observed the previous summer and fall. A caragana hedge had occupied the upslope position on this site for several years, and although recently removed, it was thought that it may have contributed to the creation of this seep. A survey of both the upper and lower slope positions was undertaken to find proof of this. All survey sites are shown in Figure 5.3.

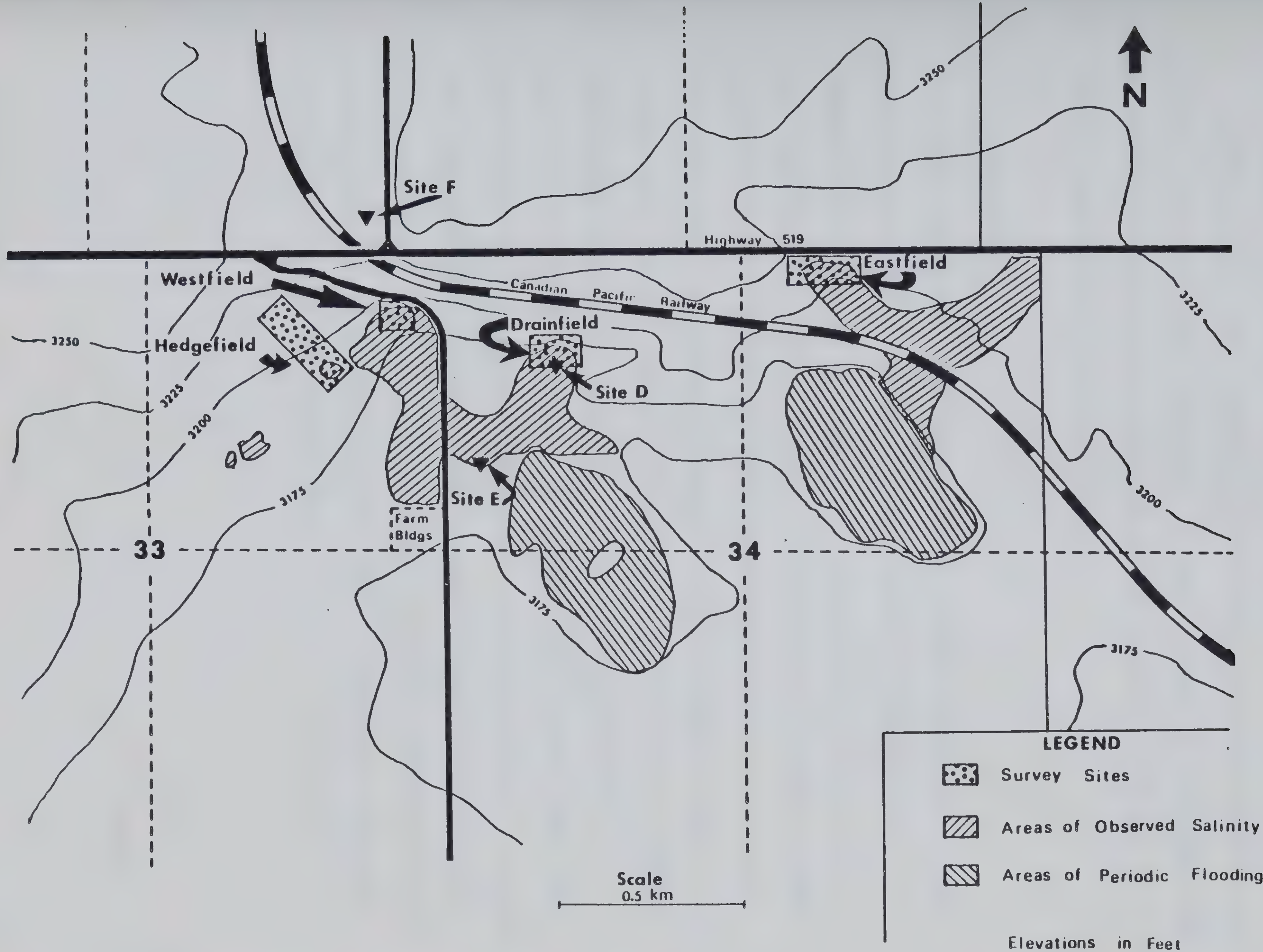


Figure 5.3 Location of the survey and monitoring sites near Nobleford.

5.1.2 Monitoring Sites

Three sites were chosen in 1978 for periodic monitoring of soil moisture and salinity. An upperslope, a midslope and a lowerslope site were selected and are shown as Sites F, D and E respectively on Figure 5.3.

5.2 LETHBRIDGE SITES

The locations that were chosen on the property of the Agriculture Canada Research Station are climatically comparable to those at Nobleford. Three monitoring sites were selected in 1978, two of which were located 25 m apart at NE-6-21-9-W4 where evidence of encroaching saline seeps was observed in a field adjacent to an irrigation canal (see Figure 5.4). These sites are referred to as Sites A and B. The third monitoring site, Site C, was selected at SE-6-21-9-W4 where rotation of agricultural crops has been undertaken for several decades. The field has been irrigated on a regular basis during each growing season. The purpose of these sites was to provide data on other conditions that could lead to soil salinization, and therefore be used in comparison to the Nobleford data.

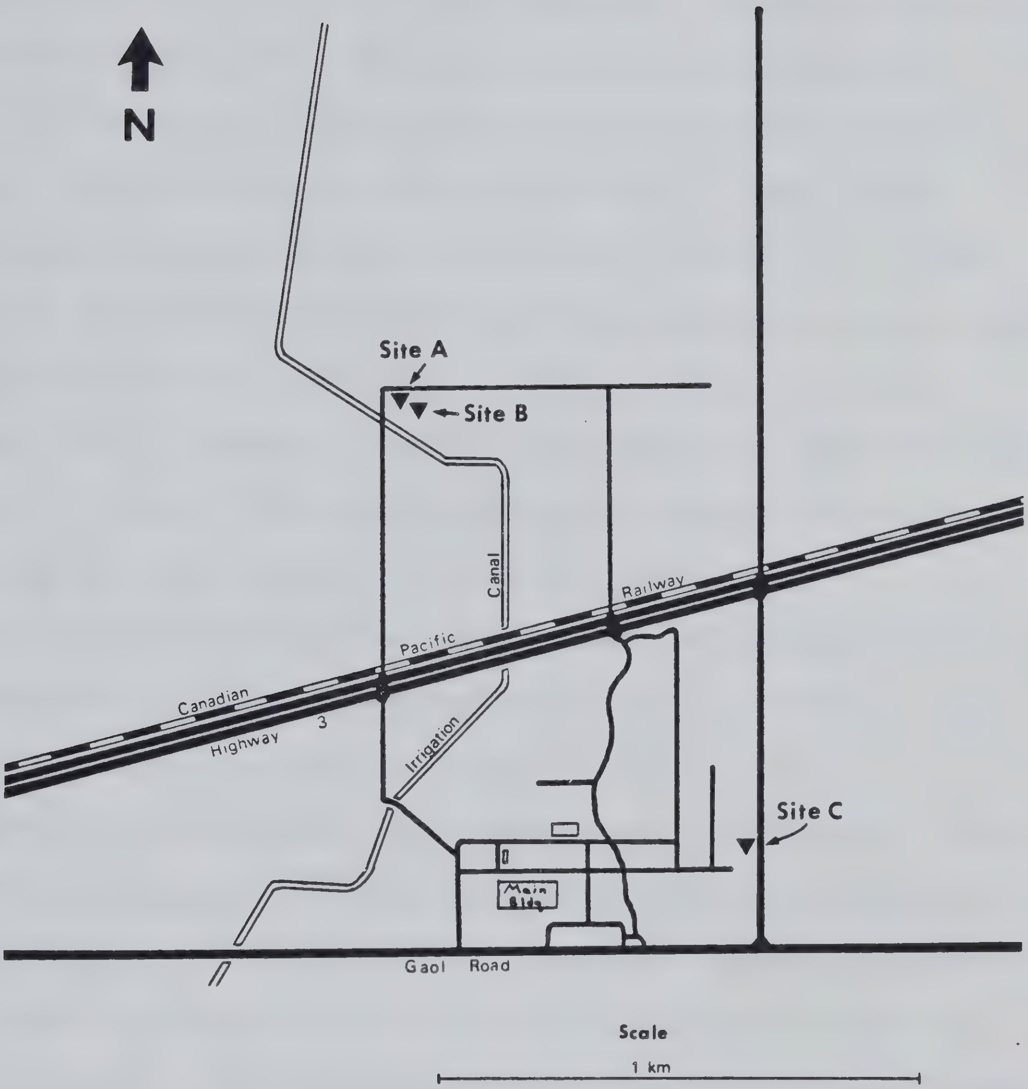


Figure 5.4 Location of the monitoring sites at the Lethbridge Research Station.

VI. MATERIALS AND METHODS

6.1 FIELD INVESTIGATIONS

6.1.1 Survey Activities

Saline seeps were in evidence at all chosen sites, and in previous years they had been observed expanding upslope. In the spring of 1978, the pasture grasses immediately uphill from the seep outbreaks were exhibiting the lush growth indicative of an encroaching saline seep. These locations were chosen as sites for the survey activities, although the Drainfield site also included the area in which subsurface drainage had been installed. Each site was divided into a number of square grids 20 m on each side. At each site the grid was large enough to extend well beyond the area of lush growth into the salt-crusted and kochia-invaded areas where the seep was more established. It was assumed that these areas would provide a range of soil salinity from non-saline to highly saline.

Measurements were to be taken at each gridpoint. Since salinity contour maps would be constructed from the data, the gridpoints were marked in a permanent manner in order to facilitate repeated surveys at different times during the growing season. Each gridpoint, once surveyed with a transit and surveying chain, was marked with a square sheet of metal, 4 cm per side, and then painted fluorescent red for easy identification. To discourage their removal by cattle, the metal squares were fastened to the ground by a spike 15

cm in length.

The measurements were taken in such a way that at each gridpoint four-electrode resistivities would be measured immediately before a soil sample was taken by a core tube powered by a Giddings drill on a 3/4 ton truck. The four-electrode a-spacings were 30 cm, 60 cm, 90 cm and 120 cm at each gridpoint, and the soil samples were divided into depth segments of 0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm depths. At each sampling location, temperatures were taken at depths of 15 cm, 45 cm, 75 cm, and 105 cm.

Due to limited access to the coring truck, one set of measurements was to be made at each site in the spring, summer, and in autumn. It was hoped that the times of these measurements would demonstrate the suitability of the four-electrode method under conditions of relatively uniform soil moisture and temperature (spring), steep soil moisture and temperature gradients (summer) and inverse soil temperature gradients and possibly soil moisture gradients (autumn). These would be representative of the range of conditions found if use of the four-electrode method was to be undertaken during the growing season.

No measurements were taken during 1978 because of malfunctions in the resistance meter, and associated servicing delays. Precipitation during 1978 was above average and by the spring of 1979 the seeps at the Westfield and Eastfield sites exhibited increased discharge. Water had ponded over a small portion of the Westfield and a large

portion of the Eastfield site. The persistence of ponded water at Eastfield did not allow measurements at this site during the summer, and by 1980 it was abandoned in favor of the Hedgefield site.

6.1.2 Survey Instruments

The four-electrode apparatus that was used on a trial basis in 1978 consisted of a Bison model 2350 A earth resistivity meter and a wooden beam 3.66 m in length upon which were supported a series of stainless steel electrodes. The electrodes were electrically wired and spaced from each other in such a way that the desired a-spacings could be controlled with the turn of a switch . This beam was found to be cumbersome to carry, both in a vehicle and by foot in the field, and after numerous broken connections, it was abandoned in favor of four individual probes in June 1978. The individual probes were each made of 1 cm diameter aluminum rod, 30 cm in length. The rods were sharpened at one end and then bent 90 degrees at the opposite end. The short ends were drilled and tapped to hold a threaded steel rod, 3 mm in diameter. In this manner they were able to accommodate an alligator-type electrical connector that could easily be removed when the electrodes were not in use. A measuring tape, laid along the ground where each measurement was to take place, provided the means for proper a-spacing. Figure 6.1 illustrates the way the individual probes were used. Measurements in the spring of 1979 and

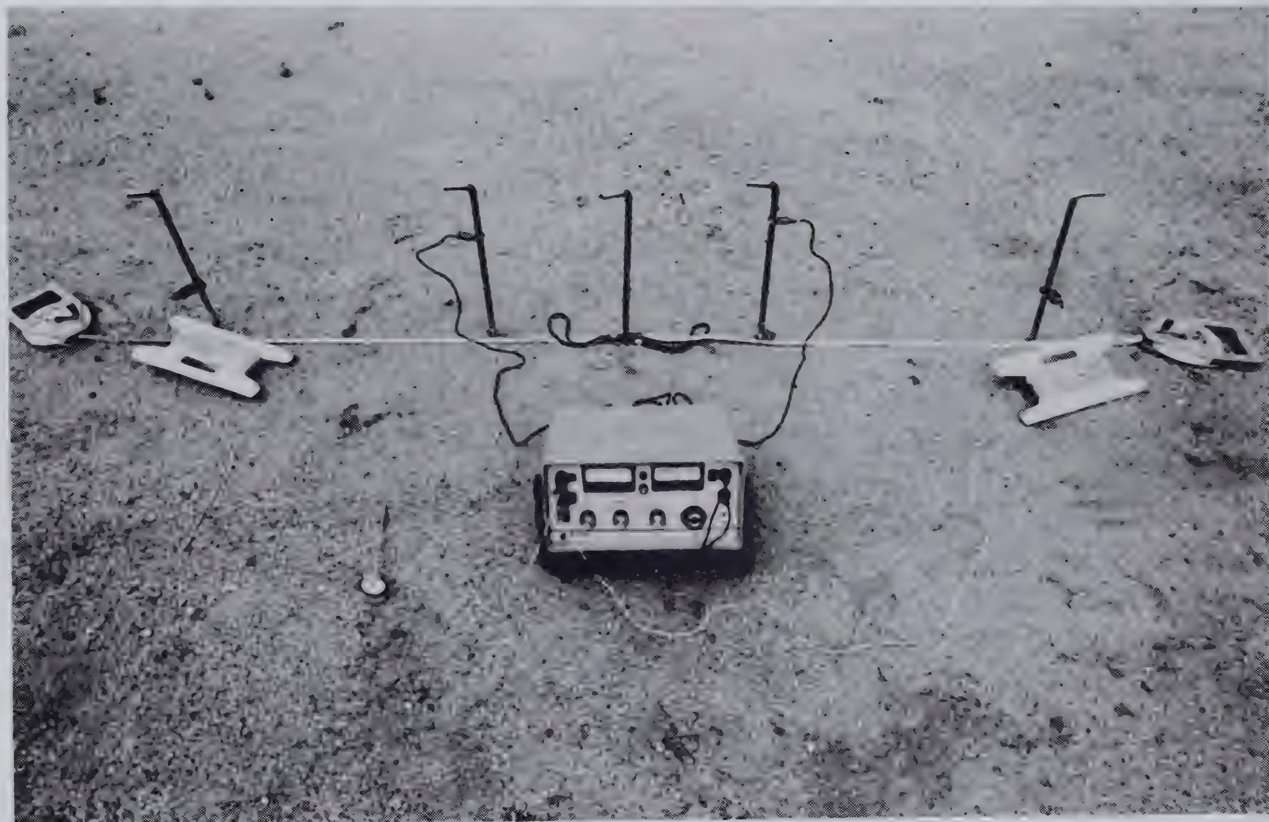


Figure 6.1 A four-electrode apparatus similar to the one used in this study. The centre probe is only used to anchor the measuring tapes. Reprinted from Rhoades and Halvorson, 1977.

1980 were taken using the four individual electrodes and a Soiltest model RC-40 Strata Scout earth resistivity meter. Measurements in the summer and autumn of 1979 were also taken with the individual electrodes but with a Biddle model ET-5 Megger Meter earth resistivity meter.

Soil samples for laboratory analysis were taken with a 5 cm diameter sampling tube which was pushed into the ground to a depth of usually greater than 120 cm. Once the tube was removed from the ground, samples were taken from the tube, divided into 30 cm lengths and sealed in plastic bags.

Soil temperatures were obtained with a stainless steel probe that was pushed into a hole made by a 2.5 cm diameter sampling tube. The temperature was measured using four brass rings, located on the shaft and having diameters slightly larger than the stainless-steel shaft. The rings were designed to accommodate a thermistor, and were spaced 30 cm apart on the probe. Each ring had a slightly different diameter than the others and they were arranged on the probe in decreasing diameter size, with the largest ring occupying the uppermost position on the probe. This method provided the best possible contact between the rings and the soil. The shape and dimensions of the probe are illustrated in Figure 6.2. When the probe was inserted to a depth of 120 cm in the ground, the rings were located at depths of 15 cm, 45 cm, 75 cm and 105 cm. The probe was designed specifically for this project. To obtain additional soil temperature information, a pocket thermometer was inserted into the soil

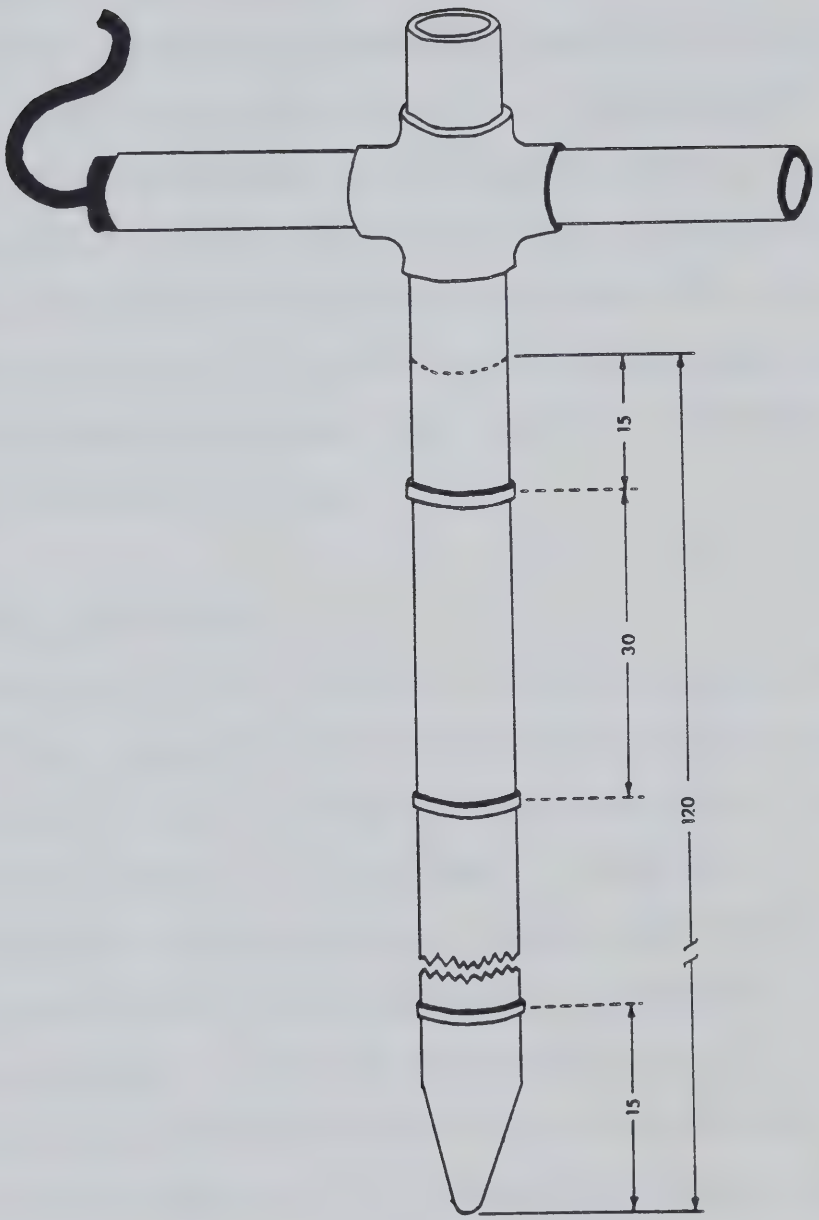


Figure 6.2 Soil temperature probe.

to a depth of 2 cm during measurements at each gridpoint.

Measurements of resistivity and temperature, and the collection of soil samples took place at each gridpoint for each survey. An exception to this method was the Hedgefield survey where time constraints permitted sampling at only one of every four gridpoints, while resistivity measurements were taken at every gridpoint. The gridpoints varied, being 20 m apart downhill from the "hedge" and 10 m apart uphill from the hedge. The greater intensity was required in the uphill portion of the site in order to aid in the possible detection of recharge activities that would be initiated by the snowdrifts behind the hedge.

6.1.3 Monitoring Activities

Weekly monitoring took place at sites A and B from May of 1978 until late August of that year. Monitoring of sites C through F began in June of 1978 and continued until late August. Monitoring resumed in early May of 1979 and continued at all six sites until late August. Monitoring activities included water table depth, soil moisture content, soil salinity , and soil temperature. A meteorological field station at Site E provided data for precipitation, soil temperature at a depth of 10 cm, wind, and evaporation for the Nobleford sites. Similar data for the Lethbridge sites were provided by a meteorological station at the Agriculture Canada Research Station, Lethbridge, Alberta. At each site, soil samples were taken

for physical analyses.

6.1.4 Monitoring Instruments

Soil moisture measurements were performed with a Campbell Pacific neutron probe using access tubes that were installed to a depth of 2 m. The probe was lowered to depths of 15, 45, 75 and 105 cm for each measurement, and the final count value was determined from an average of three one-minute counts.

Soil salinity measurements were made with Soilmoisture model 5000-A in situ salinity sensors and a Soilmoisture model 5500 Salinity Bridge. Only one sensor was available in 1978, and it was installed at Site A, Lethbridge. By the spring of 1979, twelve sensors were available, and were installed as shown in Table 6.1. All sensors had been calibrated at the factory, and the calibrations were checked in solutions of Na^{+}, Ca^{+2} and Cl^{-} of known electrical conductivity, prior to their installation in the field. Weekly measurements, whenever possible, were also made at each site with the four-electrode apparatus during 1978 and 1979. The four-electrode a-spacings were 30 cm, 60 cm, 90 cm and 120 cm.

Soil temperatures were obtained by means of the thermistors that are included in the Soilmoisture model 5000-A salinity sensors, as well as by thermocouples that were installed in 1979. Locations of the soil temperature instrumentation are presented in Table 6.1. Late in 1979, a

Table 6.1 Location of the salinity sensors and thermocouples at the monitoring sites.

SITE	15 cm	45 cm	75 cm	105 cm
SITE A	X 0			X 0
SITE B		X 0	X	
SITE C	X	X	X	
SITE D	X		X	
SITE E	X	X 0		X
SITE F	0	0		

X = Salinity sensor installation

0 = Thermocouple installation

means was devised whereby the temperature probe could be incorporated into the monitoring activities by coring a 2.5 cm diameter hole and insulating it, when not in use, with a 2.5 cm diameter PVC tube filled with dry sand. This enabled repeated measurements at the same hole using the temperature probe.

Water table depths at all sites were obtained by installing a slotted PVC pipe. Measurements were made with a rubber tube through which air could be blown. The tube was marked in increments of 1 cm.

Meteorological data, consisting of evaporation from a class A pan, precipitation, air and soil (10 cm depth) temperatures were obtained from the field meteorological station at NW-34-23-10-W4 and from the Lethbridge Research Station, both courtesy of Agriculture Canada.

6.2 LABORATORY ANALYSES

6.2.1 Chemical Analyses

All samples were analyzed for the pH of a saturated paste and the electrical conductivity of a saturation extract (U.S. Salinity Laboratory Staff, 1954). The extract was further analyzed for content of Na^{+}, Ca^{+2} and Mg^{+2}, SO_4^{-2} and Cl^{-} using the Technicon Autoanalyzer II (Chang and van Schaik, 1965).

6.2.2 Physical Analyses

Moisture content of all samples was determined by the gravimetric method for both field moisture content and saturation moisture content from a saturated paste. Samples from each site were also analyzed for sand, silt and clay content. Particle size analysis for the Hedgefield site and all of the monitoring sites was performed using the hydrometer method (Day, 1965). Analysis of samples from the Westfield and Drainfield sites was performed using the pipette method for clay content (Day, 1965) and wet sieving through a 53 m sieve to obtain the content of the sand fraction.

Bulk densities were obtained by sampling representative portions of the fields where the sites were located, by means of thin-walled Shelby tubes powered by the Giddings core machine (American Society of Testing Materials, no. D-1587-74, 1974). The dimensions of the sample and the tube were measured, then the sample was extruded. Once the oven-dry weights were obtained, bulk densities were calculated.

6.3 DATA ANALYSES

6.3.1 Survey Data

Comparison of ECa values (four-electrode measurements) and the ECe values (saturation extract analyses) were made using multiple linear regression techniques. The analyses consisted of regressing different groups of the measured

independent variables against ECe. The method of introduction of the independent variables was in decreasing order of their correlation with ECe, as indicated by r.

Three comparisons have been made for each survey and the comparisons were designed to investigate the following relationships:

a. the effect of ECa and variables for field soil moisture content, soil temperature, percent sand, and percent clay upon the dependent variable ECe, when all variables are cumulative averages for depths 0-30 cm, 0-60 cm, 0-90 cm and 0-120 cm. The variables are labelled ECA, H2O, TEMP, SAND, CLAY, and ECE respectively.

b. the effect of the four-electrode conductivity and variables for field soil moisture content, soil temperature, percent sand, and percent clay upon ECe when all variables apply to the discrete depths of 0-30 cm, 30-60 cm, 60-90 cm, and 90-120 cm. The apparent electrical conductivity for discrete depths, ECx, can be calculated from ECa using equation 4.12.

c. the effect of ECa and variables H2O, SAND, and CLAY upon ECe when ECa is corrected by the temperature correction factors determined by the United States Salinity Laboratory Staff (1954), presented in Table 6.2. This is the method used by many of the authors of previous four electrode studies. The corrected ECa variable is labelled ECAT.

Table 6.2 Temperature factors (Ft) for correcting resistance and conductivity data to the standard temperature of 25 C.
(Reprinted from U.S. Salinity Laboratory Staff, 1954).

°C	F_t	°C	F_t
-1.0	1.95	22.0	1.064
0.0	1.88	22.2	1.060
1.0	1.82	22.4	1.055
2.0	1.76	22.6	1.051
3.0	1.709	22.8	1.047
4.0	1.660	23.0	1.043
5.0	1.613	23.2	1.038
6.0	1.569	23.4	1.034
7.0	1.528	23.6	1.029
8.0	1.488	23.8	1.025
9.0	1.448	24.0	1.020
10.0	1.411	24.2	1.016
11.0	1.375	24.4	1.012
12.0	1.341	24.6	1.008
13.0	1.309	24.8	1.004
14.0	1.277	25.0	1.000
15.0	1.247	25.2	.996
16.0	1.218	25.4	.992
17.0	1.189	25.6	.988
18.0	1.163	25.8	.983
18.2	1.157	26.0	.979
18.4	1.152	26.2	.975
18.6	1.147	26.4	.971
18.8	1.142	26.6	.967
19.0	1.136	26.8	.964
19.2	1.131	27.0	.960
19.4	1.127	27.2	.956
19.6	1.122	27.4	.953
19.8	1.117	27.6	.950
20.0	1.112	27.8	.947
20.2	1.107	28.0	.943
20.4	1.102	28.2	.940
20.6	1.097	28.4	.936
20.8	1.092	28.6	.932
21.0	1.087	28.8	.929
21.2	1.082	29.0	0.925
21.4	1.078	29.2	.921
21.6	1.073	29.4	.918
21.8	1.068	29.6	.914

For each depth of each survey, data for the independent variables was entered into the correponding equation that was derived from the relationships established between ECE and ECA, H2O, TEMP, SAND, and CLAY as a result of the regression analyses. The values that were generated, labelled ECe', gave a predicted value of electrical conductivity that approximates ECe. Soil salinity contour maps were then drawn by computer for the values of ECe', and similar maps drawn for ECe values, for each depth of each survey. Comparisons were then made between pairs of maps of ECe' and ECe, as well as between maps of the different surveys. An exception to this was the Hedgefield survey where only data taken at locations where sampling occurred was used in deriving the equations. Resistivity data collected from the other Hedgefield gridpoints were converted to ECe' using the equations of the relationships established through the regression analysis.

6.3.2 Monitoring Data

Data collected from the monitoring events were used to estimate salt movement into and out of the top 30 cm at each site. In the top 30 cm of soil, the four-electrode and the neutron probe measure approximately the same soil volume, therefore moisture content and electrical conductivity data were easier to compare in this soil layer than in soil layers encompassing a greater depth range. Salt mass was calculated from the following equation:

$$S = TDS(g/L) * \theta * 3000(cm^3\ soil)/1000(cm^3/L) \quad (6.1)$$

where S = salt mass (g),

θ = vol H_2O(cm^3/cm^3 soil)

Total dissolved solids (TDS) were calculated from electrical conductivity data from the salinity sensors and four-electrode measurements, using equations 3.2 and 3.3. Volumetric moisture contents were obtained from neutron probe measurements and total soil volume was considered to be a hypothetical cylinder with an area of 100 cm^2 and length of 30 cm. Salt fluxes across the bottom face of the cylinder were then calculated from differences in salt mass between successive monitoring events. By using a plane with an area of 100 cm^2, salt fluxes become numerically equal to tonnes/ha.

VII. RESULTS AND DISCUSSION

7.1 RESULTS OF MONITORING ACTIVITIES

7.1.1 Water Table, Soil Moisture and Salinity Fluctuations

Water table fluctuations and weekly total precipitation for the 1978 and 1979 growing seasons are shown in Figures 7.1 to 7.3, for all sites except Site F, the recharge site, where the water table continuously remained below the depth of instrumentation (235 cm). At Sites A through C, Lethbridge, and Sites D and E, Nobleford, the water table persisted within 120 cm of the surface for most of the growing season of 1978. During the 1979 growing season, the precipitation was considerably lower, and all sites showed a correspondingly longer period of time where the water table was below 120 cm. It should be noted that Site C is located in a field that is subject to irrigation. Despite a regular irrigation schedule, only on one occasion (July 4, 1978) did the water table show any noticeable response to the irrigation activities, and on this occasion the measurement took place during an irrigation event. During 1979, the sites that showed the greatest drop in the water table level were Sites B and C. The water table level at Site B dropped below the depth of the well during 1979, and a period of no measurement existed until a new well was drilled in August. Site F, being in an area of recharge, was not considered in these comparisons. Despite Site C showing little response to irrigation, all sites showed rapid and very noticeable

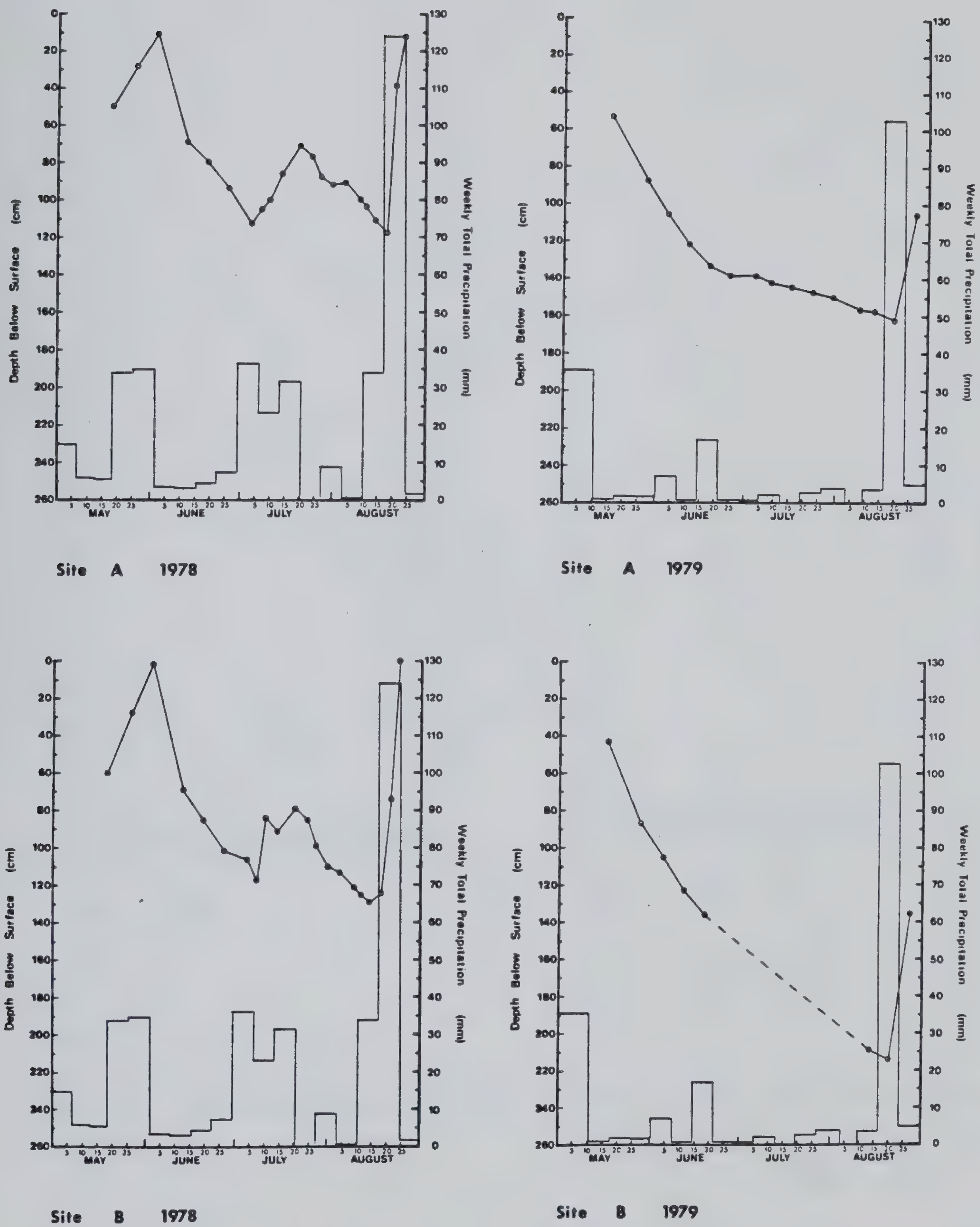


Figure 7.1 Water table depths and weekly total precipitation at the Lethbridge sites.

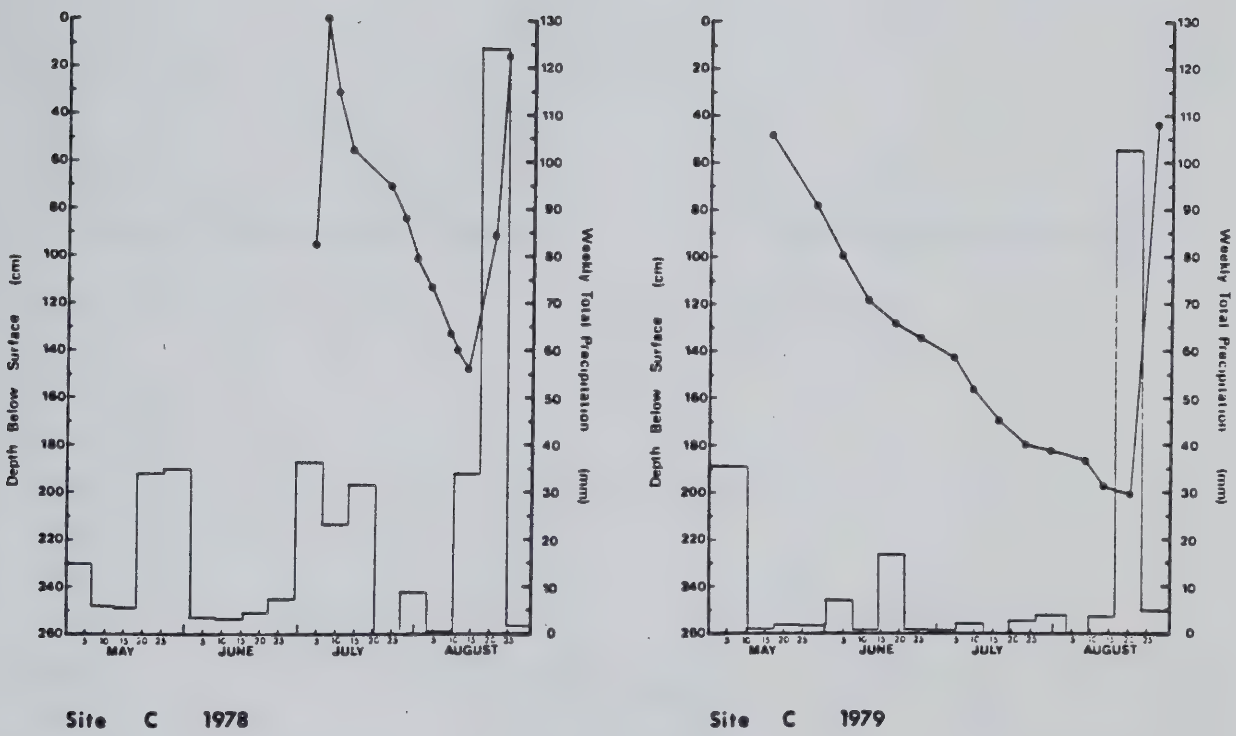


Figure 7.2 Water table depths and weekly total precipitation at the Lethbridge sites.

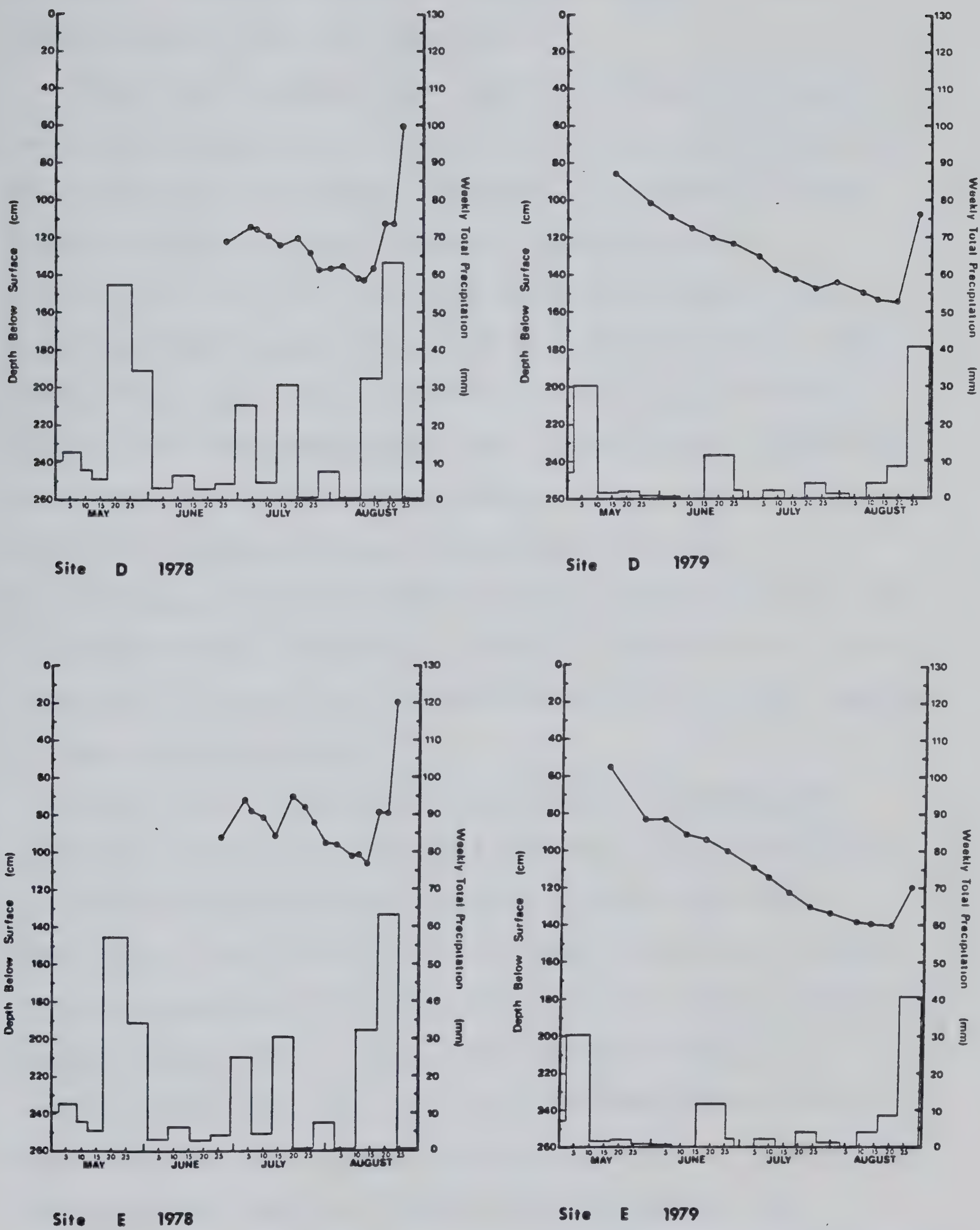


Figure 7.3 Water table depths and weekly total precipitation at the Nobleford sites.

response to the heavy precipitation events of 1978 and 1979. The water table rose during 3 separate events in 1978 (except Site C) and one event in 1979.

Soil salinity data from the four-electrode and salinity sensor measurements, and weekly total evaporation data from the class A pan are shown in Figures 7.4 through 7.9 for Sites A through E. Examination of the electrical conductivity data for the sites shows that Sites B and C have the lowest overall rootzone soil salinity of all the 5 sites. These were the two sites that, with the exception of site F, had the lowest water table levels during 1979. Site F had such low and unvarying salinities that they are not presented. Evaporation data collection from the meteorological field station at NW-34-23-10-W4 (Site E) was interrupted four times during 1978 and twice during 1979 due to cattle drinking from the evaporation pan, and the jamming of the recording charts.

The original plan was to apply the four-electrode calibration equations developed from the survey activities to the four-electrode measurements obtained from the monitoring sites, since the soils were of similar textural class. A comparison with the data obtained from the salinity sensors showed that in most cases the electrical conductivities from the four-electrode measurements vastly underestimated the values given by the salinity sensors. The Hedgefield calibration equation was derived from the greatest range of salinities, and from temperatures and soil

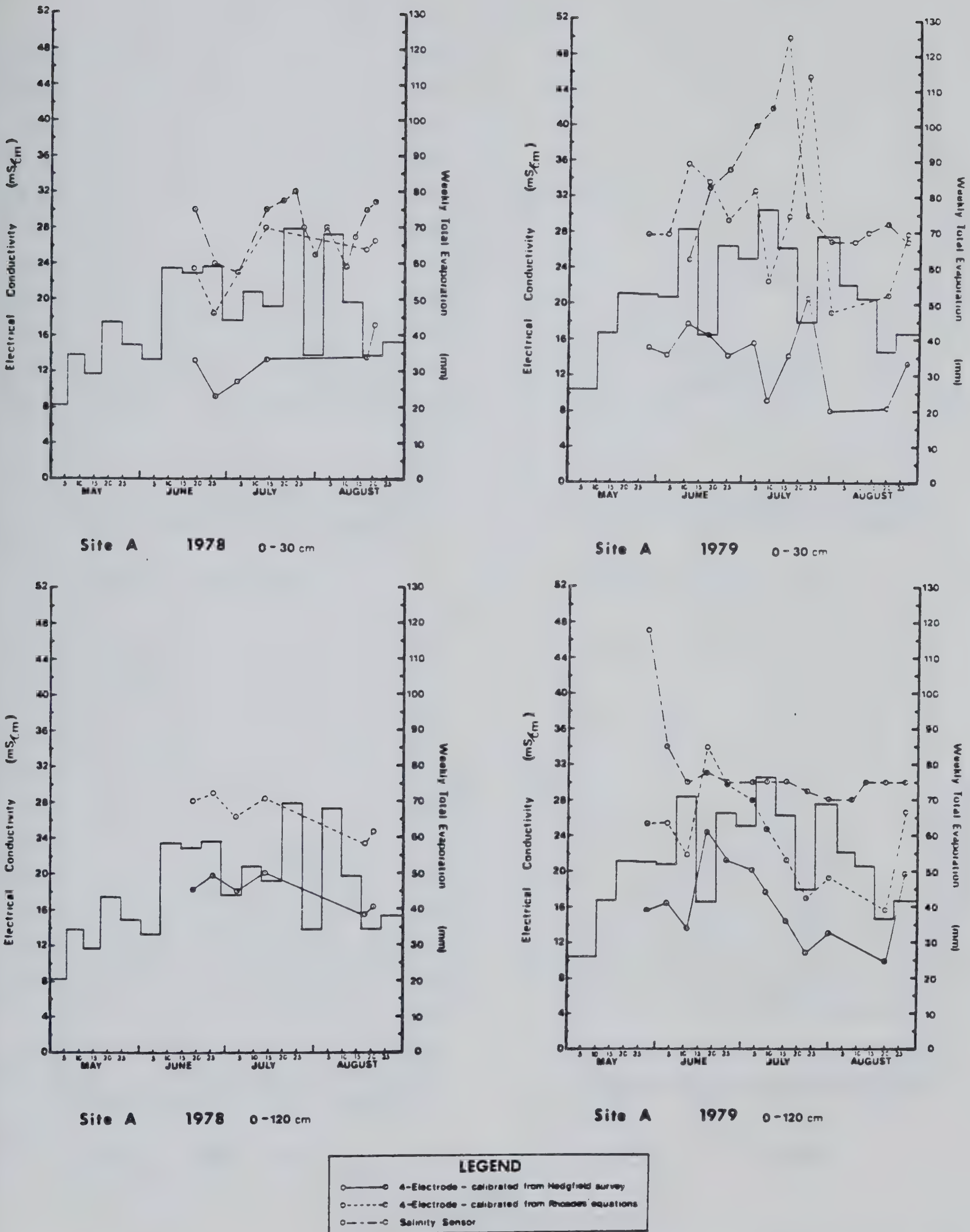


Figure 7.4 Soil salinity fluctuations and weekly total evaporation from Lethbridge sites.

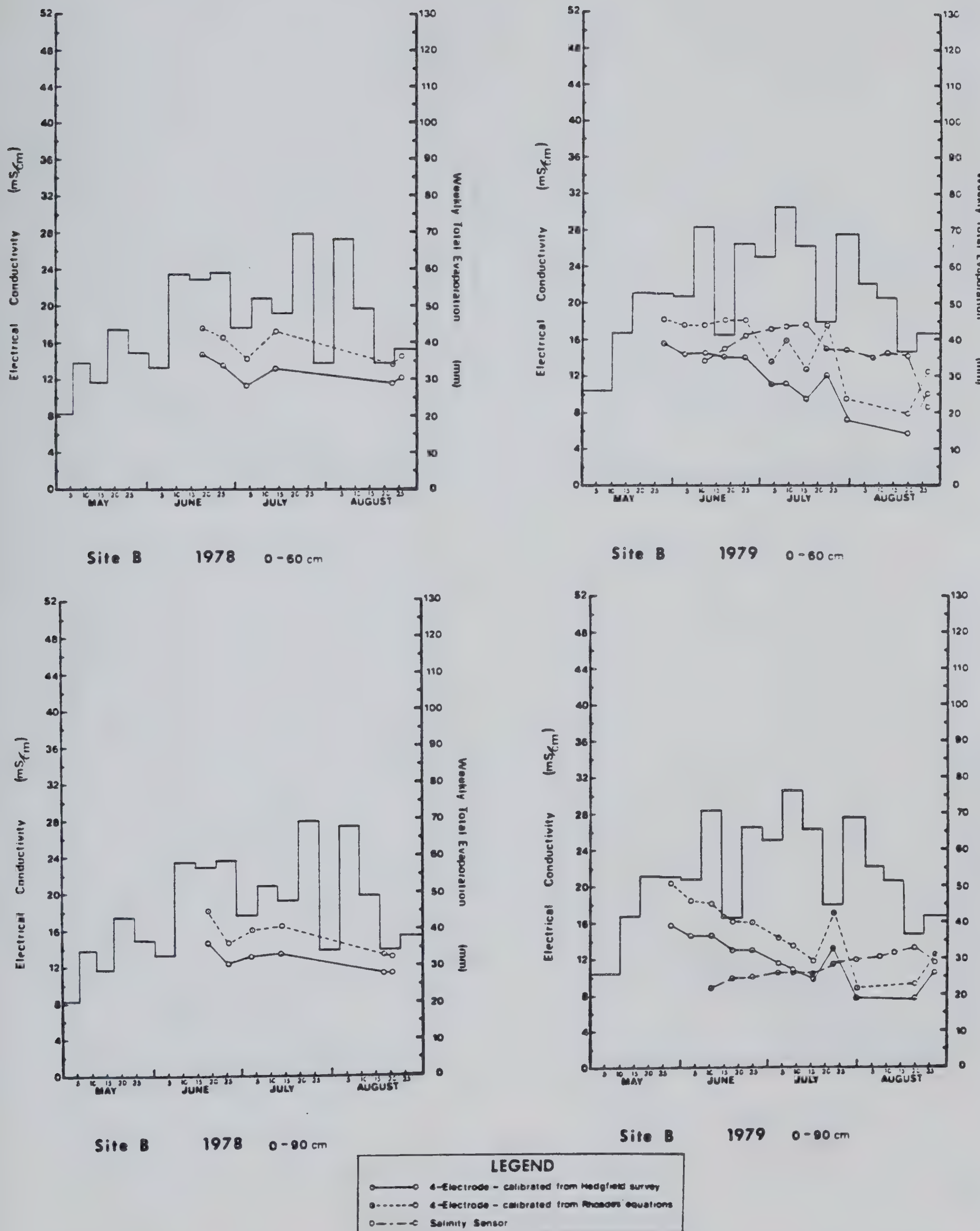
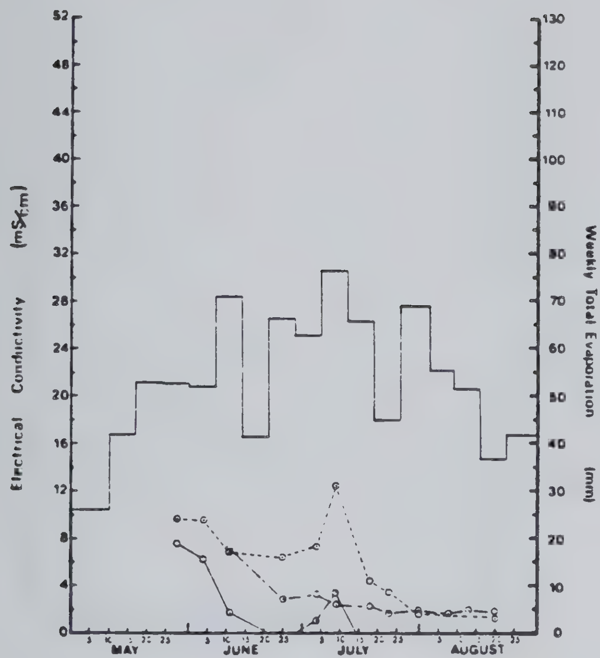
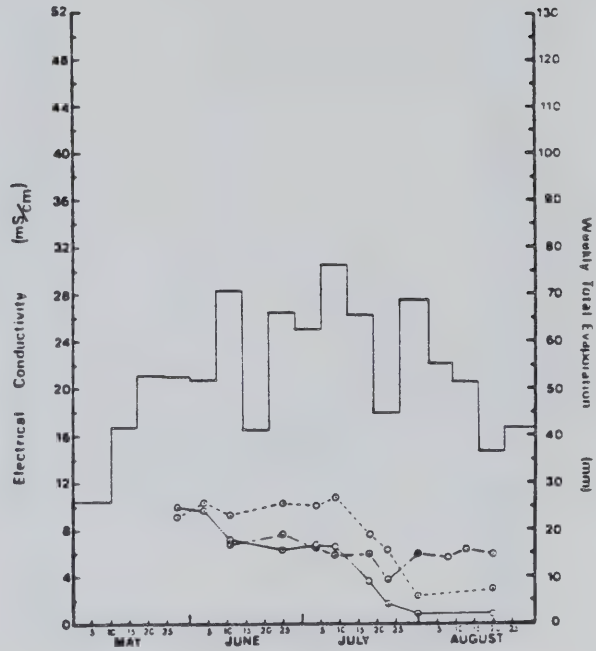


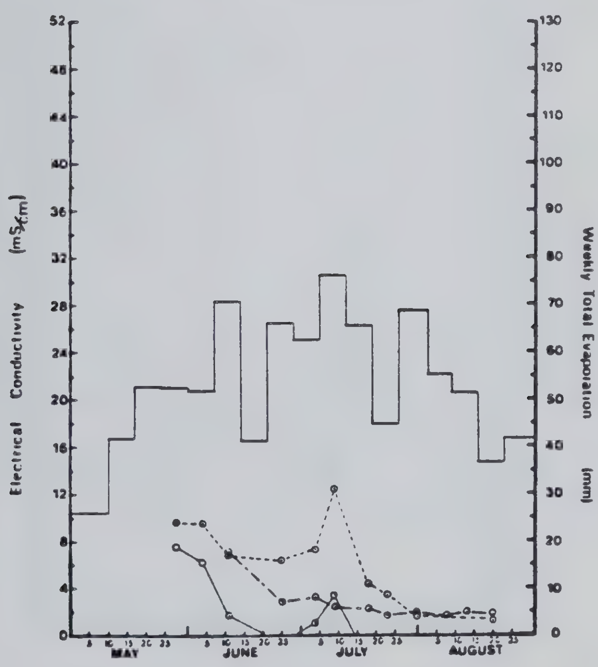
Figure 7.5 Soil salinity fluctuations and weekly total evaporation from Lethbridge sites.



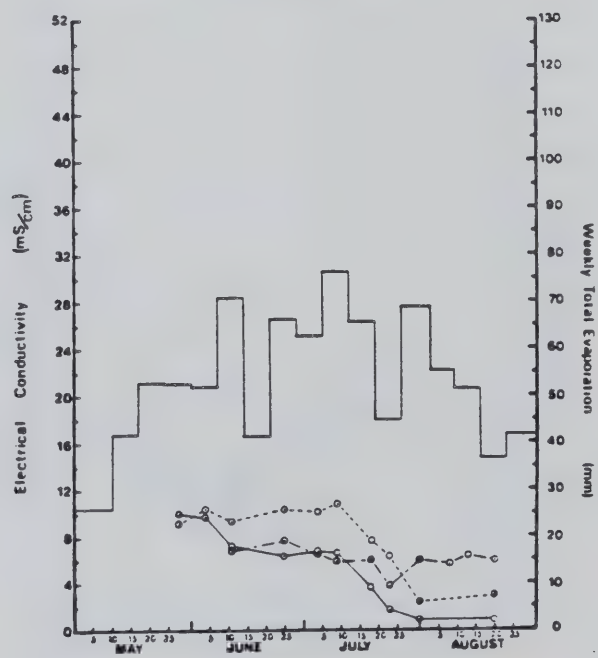
Site C 1979 0-30 cm



Site C 1979 0-60 cm



Site C 1979 0-90 cm



Site C 1979 0-120 cm

LEGEND

4-Electrode - calibrated from Hedgfield survey
4-Electrode - calibrated from Rhoades equations
Salinity Sensor

Figure 7.6 Soil salinity fluctuations and weekly total evaporation from Lethbridge sites.

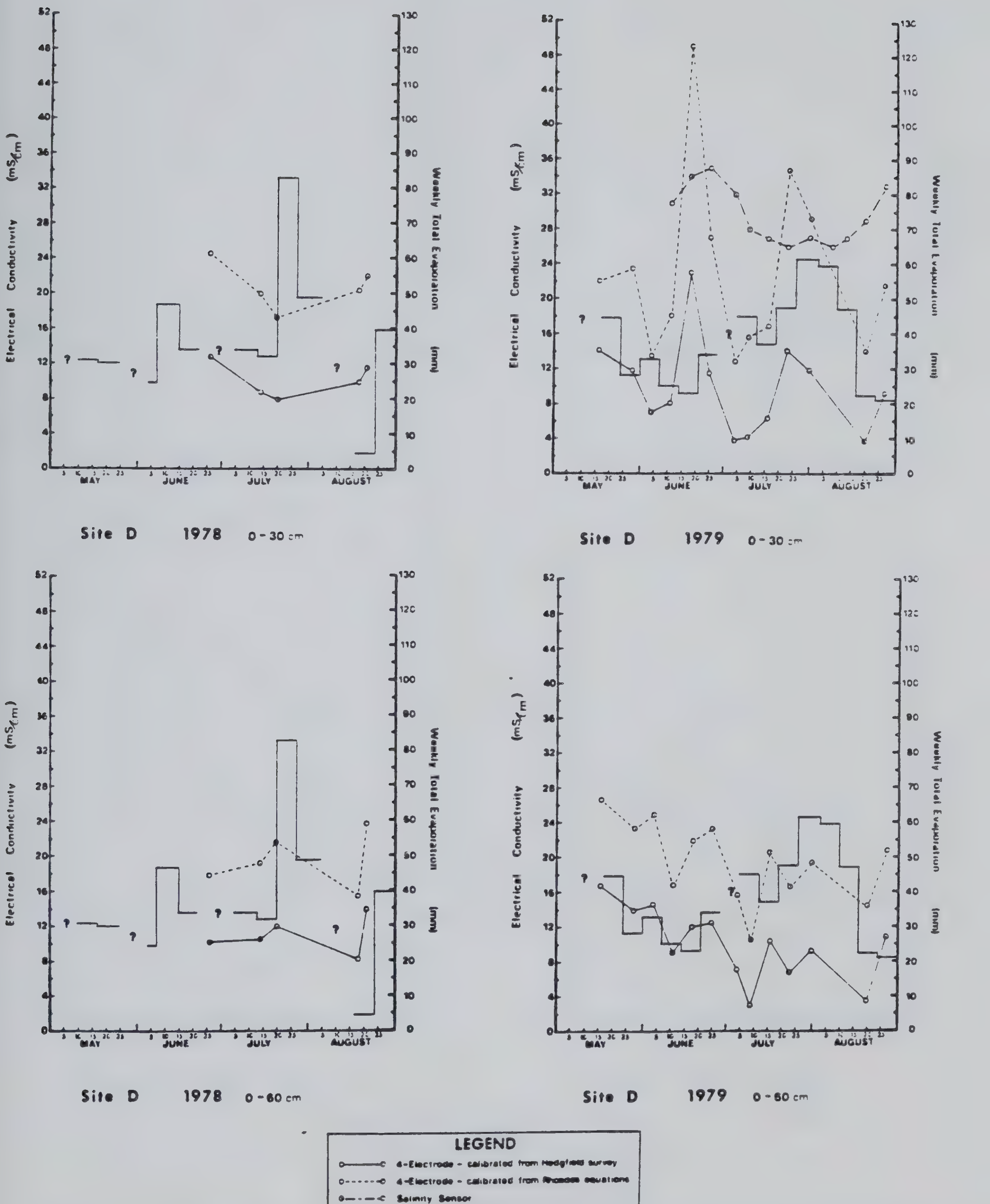


Figure 7.7 Soil salinity fluctuations and weekly total evaporation from Nobleford sites.

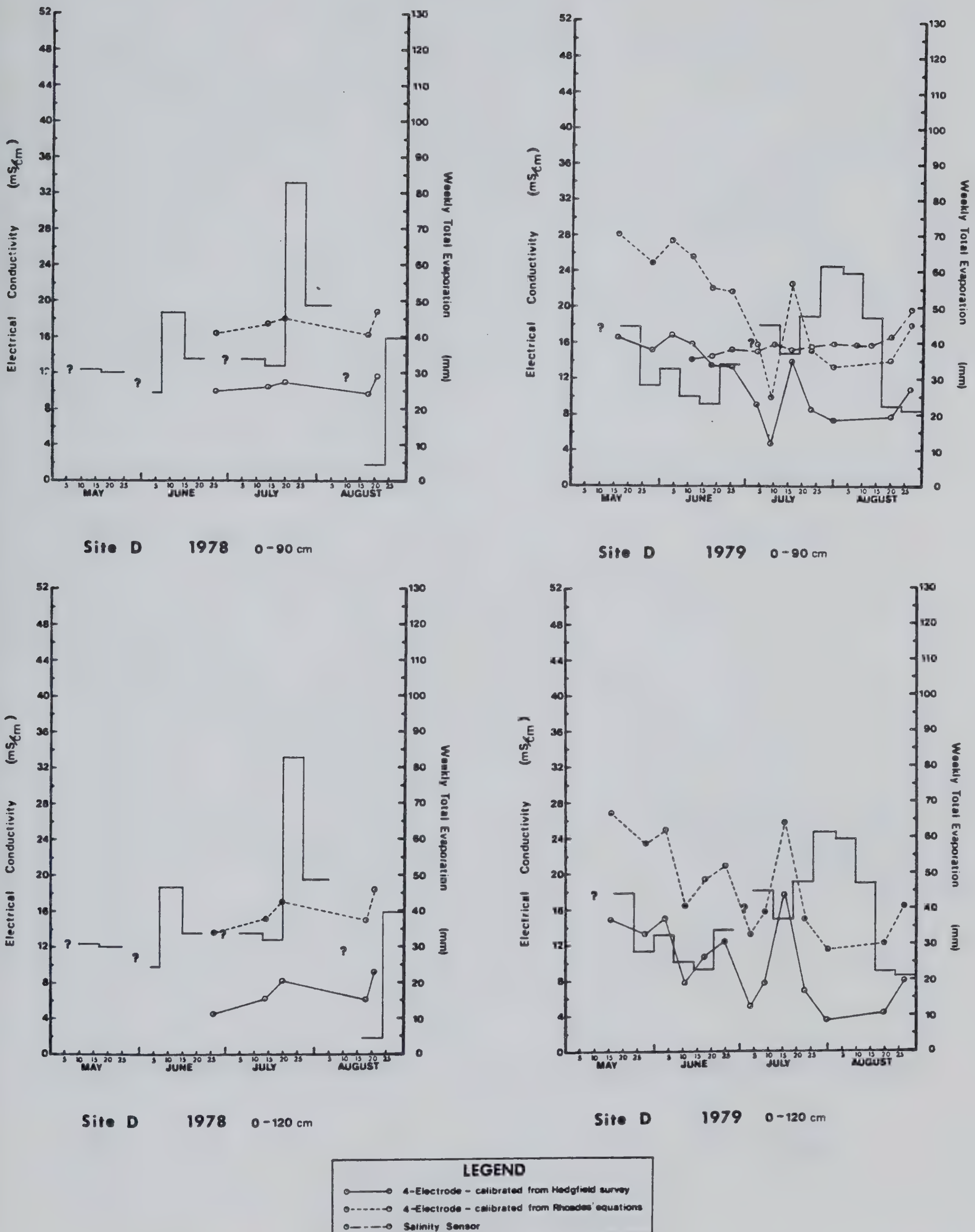


Figure 7.8 Soil salinity fluctuations and weekly total evaporation from Nobleford sites.

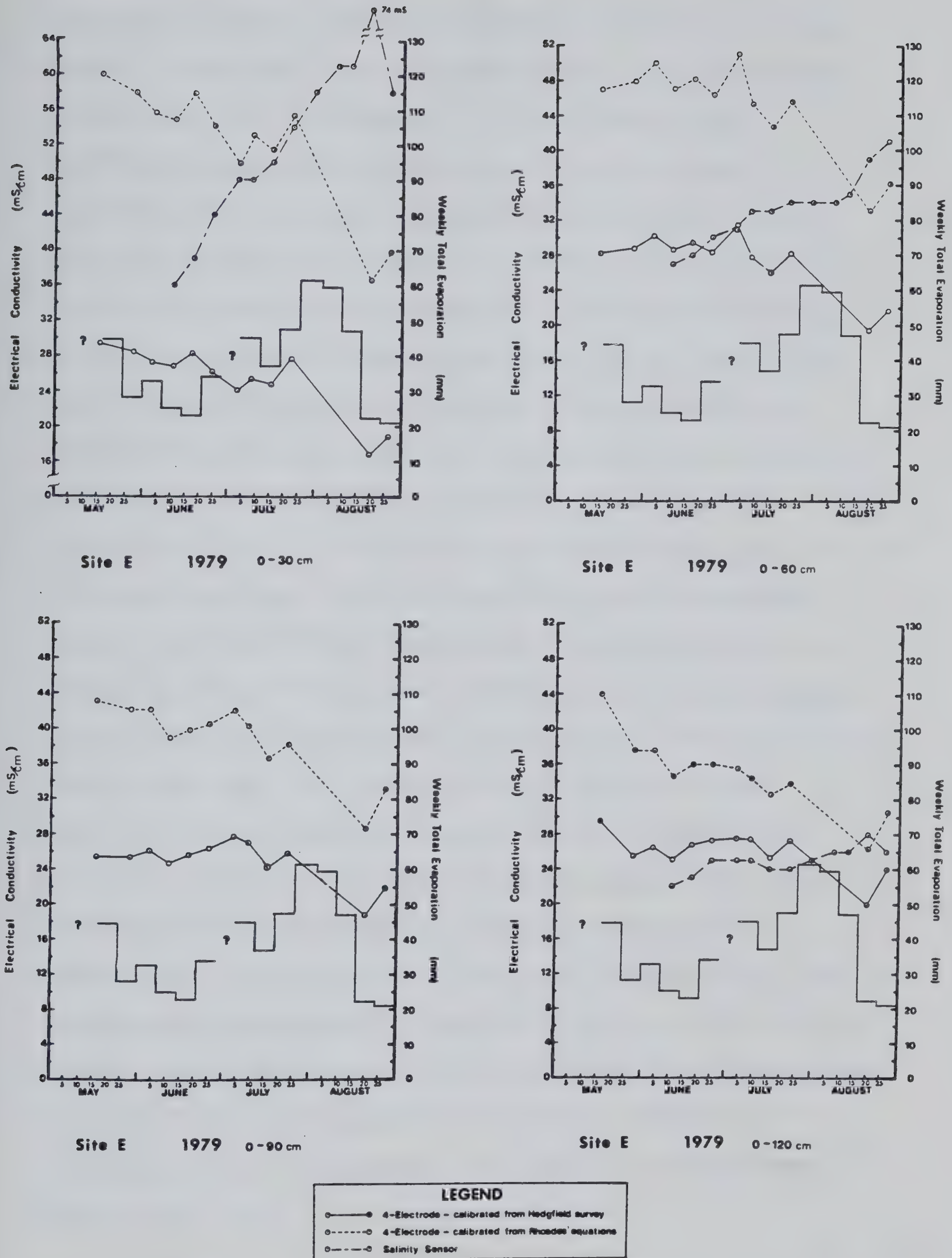


Figure 7.9 Soil salinity fluctuations and weekly total evaporation from Nobleford sites.

moisture contents that were comparable with most of the sites. In addition, it generated electrical conductivity values that were the highest of any of the survey calibration equations, and therefore most closely approximated electrical conductivities as given by the salinity sensors. This equation was used to calculate the electrical conductivity values for the monitoring sites. Since the calibration equations developed by Rhoades and Halvorson (1977) would generate even higher electrical conductivity values, they were also chosen as a basis for comparison. Data from both equations are also presented in Figures 7.4 to 7.9. Originally soil temperature data were to have been obtained from the thermistor in the salinity sensor. During 1979 the sensors at Location B,placed at depths of 45 and 75 cm, were showing consistently higher values than the 15 cm sensor at Location A, only 25 m away. The sensors were then checked by placing calibrated thermocouples at the same depths and were found to be providing incorrect temperature measurements. This was later confirmed using the temperature probe. Subsequent temperature values for the Hedgefield equation were from the thermocouple measurements whenever possible. A correction factor, obtained from a simple regression analysis between the salinity sensor temperature and the thermocouple temperature for each sensor, was applied to cases where thermocouple data were not available.

The monitoring data show that salt movement, especially in the upper 30 cm, is highly dynamic at Sites A, D and E. Observations from Site A indicate that the low amount of precipitation during 1979 was characterized by a greater activity of salt movement than in 1978. The electrical conductivity curves show that in nearly all cases a noticeable increase in the measured electrical conductivity values occurred following the heavy rainfall events of August 1978 and August 1979. Another trend particularly evident at 0-30 cm depths of Sites A and B is the apparent inverse relationship between the four-electrode measurements and the evaporation data. During periods of high evaporation, the electrical conductivities are reduced, while during periods of lower evaporation, they show an increase. The salinity sensor data shows a direct response to the evaporation data. Site E had by far the most saline soil conditions, but despite the high salinities and the salt crusting that was visible within and adjacent to this site, red samphire and some pasture grasses were observed.

The salinity sensor meter provides a direct temperature-corrected electrical conductivity readout up to 40 mS/cm as well as an indirect readout of resistance. The salinity sensor measurements that exceeded 40 mS/cm are estimated from the resistance scale of the meter, and therefore have a slightly reduced degree of accuracy. Insufficient data were collected at Site C during 1978 to provide any electrical conductivity curves for that year.

The four-electrode calibration relationships developed from the Hedgefield survey and those from Rhoades and Halvorson (1977) remain close to parallel even though the Rhoades and Halvorson equation was developed, for soils of similar textural groupings, from temperature-corrected ECa only, while the Hedgefield equation is derived from ECa, percent soil moisture, temperature, percent sand and percent clay. The Rhoades and Halvorson equation generates higher electrical conductivity values which more closely approximate the salinity sensor measurements at all 0-30 cm sites. Comparisons between the two measurements are complicated by the fact that the four-electrode method provides a bulk measurement over the entire depth of measurement, while the salinity sensor measures the salinity of a small soil solution volume at its point of placement. For the 0-30 cm depth the salinity sensors were placed at 15 cm in order to give an "average" value representative of the top 30 cm. Slightly differing values for the two methods are therefore to be expected. However, the four-electrode measurements should show less variation than the salinity sensor measurements due to its larger sampling volume, and this is not the case. Since the volume of the four-electrode measurement is approximately πa^3, at depths below 30 cm the difference in sampling volumes becomes too great to make any meaningful comparisons between the salinity sensor data and the four-electrode method.

7.2 SALINITY SURVEY

When site selection was undertaken in 1978, sharp changes in vegetation were used as preliminary indicators of the extent of saline seep activity and salinity build-up in the soils of the Drainfield and Westfield sites. Similarly in 1979, a visual examination of the field where the Hedgefield site was to be located showed a small patch of the wheat crop exhibiting the lush growth characteristic of an encroaching saline seep. The contrast between this patch and the rest of the field was particularly striking considering that the summer had been very dry and the rest of the crop was exhibiting stunted growth as a result of moisture stress. The grids at each site extended well beyond the visual boundaries of salinity activity, and it was hoped that with a series of measurements over a growing season, the growth of the saline seep would be detected as it encroached on the unaffected portions of the field.

Two major problems arose which affected the results of the study. The first was the loss of time experienced when the resistivity meters required servicing. This was particularly damaging when both the Soilmoisture RC-40 Strata Scout and the Bison model 2350 A meters broke down within hours of each other in late July 1979 when the summer surveys were beginning. This resulted in only a late summer survey being conducted at the Westfield site. In total seven surveys were made:

(i) at Drainfield in May, August, and September of 1979, and

April of 1980,

(ii) at Westfield in May and September of 1979, and

(iii) at Hedgefield in April of 1980.

The second and more significant problem was that the visual estimation of the extent of the soil salinity at each site vastly underestimated the actual extent. This resulted in a lower range of soil salinities than had been hoped for.

All survey data are presented in Appendix A and the measured electrical conductivity from saturation extracts (ECe) and the predicted electrical conductivity (ECe') from multiple regression equations using four-electrode data are presented in Appendix B. The tables in Appendices A and B show that high concentrations of salt exist to within 30 cm of the soil surface in all areas of the Drainfield and Westfield sites. Only the Hedgefield site shows areas where soil salinities lie in the accepted non-saline range of 0-4 mS/cm. In some cases, such as the Drainfield survey of August 1979, the highest measured salt concentrations are found in areas where pasture grasses were growing. As a result, only at the Hedgefield site were measurements conducted over a range of low to high salt concentrations; at the Westfield and Drainfield sites measurements were taken over a range of values in the high salt concentrations only.

7.2.1 Effect of ECa, Temperature, Moisture and Texture on Predicting ECe

Data from each measurement of gravimetric soil moisture content, soil temperature, percent sand, percent clay, and ECa as measured by the four-electrode method were entered into a stepwise multiple regression program to predict ECe' which was then compared to the measured ECe of the corresponding saturation extract. The multiple regression data for each of the seven surveys are summarized in Tables 7.1 through 7.7. In each case the variables have been entered in the order of greatest effect on the correlation coefficient (r).

The summary tables show that the highest degree of correlation as expressed by the multiple r occurs for data from the Hedgefield survey. At all depths, the multiple r exceeds 0.95 and is highest at the 0-30 cm depth of measure, where it approaches 0.98. These correlations compare favorably with those of previous studies (see Table 7.8). Table 7.7 also shows that the independent variable ECa is by far the most influential predictor of ECe' and the coefficient of determination (r^2) values show that at three of the four depths, over 90 percent of the variation in ECe could be accounted for by variation in ECa, and in the 4th case, the 0-60 cm depth, 89 percent of the variation of ECe is accounted for by variation in ECa. All other independent variables exert only a small influence on the correlation coefficient. In all four cases, the significance of multiple correlation is at the 1 percent level ($p=0.01$), and simple correlation is also at the 1 percent level of significance

Table 7.1 NOBLEFORD SALINITY SURVEY #1, MAY 24, 1979 - DRAINFIELD

* * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N   S U M M A R Y * * * * * * * * * * * *

DEPENDENT VARIABLE.. ECE

DEPTH 0-30cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.79376	0.63006	0.63006	0.79376	3.519990
TEMP	0.82068	0.67352	0.04346	-0.29638	-0.6363507
SAND	0.82314	0.67756	0.00404	0.01360	0.09570796
H2O	0.82473	0.68018	0.00262	0.53011	0.1878361
CLAY	0.82542	0.68131	0.00113	0.16718	0.1791809
(CONSTANT)					1.478924

DEPTH 0-60cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.78642	0.61845	0.61845	0.78642	4.323912
SAND	0.80283	0.64454	0.02609	0.19628	0.05170537
H2O	0.80746	0.65199	0.00745	0.36263	-0.2848624
TEMP	0.81063	0.65713	0.00514	-0.05913	-0.4653148
CLAY	0.81204	0.65941	0.00228	-0.20895	-0.1629317
(CONSTANT)					15.57155

DEPTH 0-90cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.73836	0.54518	0.54518	0.73836	3.794510
CLAY	0.77306	0.59763	0.05245	-0.30044	-0.4400936
TEMP	0.79024	0.62448	0.02685	0.06284	-0.6042447
SAND	0.79173	0.62684	0.00236	0.16869	-0.03052357
H2O	0.79214	0.62748	0.00064	0.22829	-0.04341148
(CONSTANT)					19.46061

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.72112	0.52001	0.52001	0.72112	4.360525
CLAY	0.78030	0.60888	0.08887	-0.34880	-0.5958199
TEMP	0.80427	0.64684	0.03797	0.21026	-0.6410950
SAND	0.81330	0.66145	0.01460	0.15052	-0.05802072
(CONSTANT)					20.23295

Table 7.2 NOBLEFORD SALINITY SURVEY #2, AUG 21-24, 1979 - DRAINFIELD

* * * * * * * * * * * * * MULTIPLE REGRESSION SUMMARY * * * * * * * * * * * *

DEPENDENT VARIABLE.. ECE

DEPTH 0-30cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.84913	0.72103	0.72103	0.84913	5.213695
SAND	0.85768	0.73561	0.01459	0.09500	-0.3172447
H2O	0.86321	0.74512	0.00951	0.73168	-0.1833202
CLAY	0.86593	0.74983	0.00471	0.04277	-0.8314523
TEMP	0.87250	0.76126	0.01143	-0.41345	0.7231343
(CONSTANT)					22.54894

DEPTH 0-60cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.55521	0.30826	0.30826	0.55521	6.086451
H2O	0.59937	0.35924	0.05098	0.41943	-0.4429742
TEMP	0.60786	0.36949	0.01025	-0.09824	0.5269206
CLAY	0.60994	0.37203	0.00254	-0.13405	-0.3078272
SAND	0.61429	0.37735	0.00532	0.20631	-0.07172066
(CONSTANT)					10.06989

DEPTH 0-90cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.39588	0.15672	0.15672	0.39588	4.161103
CLAY	0.48541	0.23562	0.07890	-0.24356	-0.7480546
TEMP	0.52607	0.27675	0.04113	0.14607	0.5400526
SAND	0.53976	0.29134	0.01459	0.17534	-0.06630845
H2O	0.54200	0.29376	0.00242	0.15733	-0.06542291
(CONSTANT)					13.81344

DEPTH 0-120cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.32992	0.10885	0.10885	0.32992	4.960482
CLAY	0.48083	0.23119	0.12235	-0.31503	-0.8243790
H2O	0.57843	0.33458	0.10338	0.03186	-0.2882719
SAND	0.59631	0.35558	0.02101	0.23135	-0.06598120
TEMP	0.59835	0.35802	0.00244	0.19742	0.1544152
(CONSTANT)					24.63983

Table 7.3 NOBLEFORD SALINITY SURVEY #3, SEPT 29-30, 1979 - DRAINFIELD

* * * * * * * * * * * * * * M U L T I P L E R E G R E S S I O N S U M M A R Y * * * * * * * * * * * * *
DEPENDENT VARIABLE.. ECE

DEPTH 0-30cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.85138	0.72484	0.72484	0.85138	5.665322
SAND	0.86711	0.75187	0.02703	0.09699	0.2813636
CLAY	0.87256	0.76135	0.00948	-0.00846	-0.6146199
H2O	0.87274	0.76167	0.00032	0.56086	0.03384946
(CONSTANT)					10.44013

DEPTH 0-60cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.59855	0.35826	0.35826	0.59855	4.678582
CLAY	0.68803	0.47338	0.11512	-0.24045	-0.8235976
SAND	0.68996	0.47604	0.00266	0.16612	0.08274330
TEMP	0.69269	0.47976	0.00372	-0.22783	0.2638063
H2O	0.69373	0.48127	0.00150	0.17297	-0.04434290
(CONSTANT)					18.06399

DEPTH 0-90cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.45585	0.20780	0.20780	0.45585	3.193680
H2O	0.51784	0.26816	0.06036	-0.12167	-0.2074141
CLAY	0.57898	0.33521	0.06706	-0.18965	-0.7030896
TEMP	0.62289	0.38799	0.05277	0.06870	1.089862
(CONSTANT)					6.703427

DEPTH 0-120cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.44513	0.19814	0.19814	0.44513	2.801314
CLAY	0.51556	0.26580	0.06765	-0.22418	-0.7528353
SAND	0.56275	0.31669	0.05089	0.10532	-0.08903616
H2O	0.56948	0.32431	0.00762	-0.01528	-0.1128442
TEMP	0.57506	0.33070	0.00639	-0.00741	-0.3524563
(CONSTANT)					28.29366

Table 7.4 NOBLEFORD SALINITY SURVEY #4, APR 25-26, 1980 - DRAINFIELD

* * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N   S U M M A R Y * * * * * * * * * * * *

DEPENDENT VARIABLE.. ECE

DEPTH 0-30cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.48329	0.23357	0.23357	0.48329	2.206333
H2O	0.56335	0.31736	0.08379	0.43963	0.9231543
SAND	0.66432	0.44133	0.12397	0.13196	0.3984014
CLAY	0.67181	0.45132	0.01000	-0.13497	-1.068759
TEMP	0.69197	0.47882	0.02750	0.05462	0.7226049
(CONSTANT)					-12.59334

DEPTH 0-60cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
H2O	0.40968	0.16783	0.16783	0.40968	0.5558225
SAND	0.48237	0.23268	0.06484	0.27059	0.1474110
ECA	0.53862	0.29011	0.05744	0.30922	1.749477
TEMP	0.55731	0.31060	0.02049	-0.01919	0.4369269
CLAY	0.55997	0.31357	0.00297	-0.19086	-0.1738398
(CONSTANT)					-8.351043

DEPTH 0-90cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
H2O	0.30240	0.09145	0.09145	0.30240	0.4109527
SAND	0.38945	0.15167	0.06022	0.20911	0.06499174
ECA	0.43959	0.19324	0.04157	0.23558	1.180306
TEMP	0.45897	0.21065	0.01741	-0.04525	0.2643184
CLAY	0.45987	0.21148	0.00082	-0.12975	-0.05399911
(CONSTANT)					-1.448076

DEPTH 0-120cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
TEMP	0.13184	0.01738	0.01738	0.13184	0.2326520
SAND	0.14750	0.02176	0.00438	0.06734	0.01370139
H2O	0.15603	0.02435	0.00259	-0.02516	0.07116905
(CONSTANT)					9.633034

Table 7.5 NOBLEFORD SALINITY SURVEY #5, MAY 14-22, 1979 - WESTFIELD

* * * * * * * * * * * * * * M U L T I P L E R E G R E S S I O N S U M M A R Y * * * * * * * * * * * * * *

DEPENDENT VARIABLE.. ECE

DEPTH 0-30cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.77606	0.60227	0.60227	0.77606	2.620613
SAND	0.78154	0.61081	0.00855	-0.01579	0.2770186
TEMP	0.78954	0.62337	0.01255	0.62167	0.3699989
CLAY	0.79230	0.62774	0.00437	0.26222	0.2053395
H2O	0:79431	0.63093	0.00319	-0.36492	0.05137530
(CONSTANT)					-11.67280

DEPTH 0-60cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.78975	0.62371	0.62371	0.78975	4.454124
CLAY	0.82376	0.67858	0.05487	-0.07231	-0.3871432
SAND	0.83243	0.69294	0.01436	-0.17363	0.1622332
H2O	0.83294	0.69380	0.00086	-0.51497	0.03443664
TEMP	0.83315	0.69415	0.00035	0.48353	-0.05318665
(CONSTANT)					1.952959

DEPTH 0-90cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.76775	0.58943	0.58943	0.76775	5.143169
CLAY	0.81192	0.65921	0.06977	-0.12845	-0.7099858
TEMP	0.82459	0.67994	0.02073	0.39704	-0.4283721
H2O	0.82557	0.68157	0.00163	-0.59053	-0.08193890
SAND	0.82573	0.68183	0.00026	-0.02650	-0.01745434
(CONSTANT)					18.88380

DEPTH 0-120cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.77672	0.60329	0.60329	0.77672	4.536284
CLAY	0.81059	0.65705	0.05377	-0.13142	-0.3186831
H2O	0.81469	0.66372	0.00666	-0.65473	-0.2844916
TEMP	0.82821	0.68594	0.02222	0.39158	-0.4119036
(CONSTANT)					20.38924

Table 7.6 NOBLEFORD SALINITY SURVEY #6, SEPT 25, 1979 - WESTFIELD

* * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N   S U M M A R Y * * * * * * * * * * * * *

DEPENDENT VARIABLE.. ECE

DEPTH 0-30cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.64132	0.41130	0.41130	0.64132	7.170264
H2O	0.77147	0.59517	0.18388	0.08673	-1.128355
CLAY	0.79936	0.63898	0.04381	0.01852	-0.9145088
TEMP	0.82039	0.67304	0.03406	-0.39315	-1.874813
SAND	0.82135	0.67461	0.00157	0.17048	0.1069619
(CONSTANT)					74.48815

DEPTH 0-60cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.47548	0.22608	0.22608	0.47548	6.003830
H2O	0.78336	0.61365	0.38758	-0.30033	-0.8385891
CLAY	0.79048	0.62486	0.01121	-0.18372	-0.4187183
TEMP	0.79264	0.62828	0.00343	0.11813	-0.6413032
SAND	0.79303	0.62890	0.00062	-0.07587	-0.03371085
(CONSTANT)					44.73320

DEPTH 0-90cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
H2O	0.44606	0.19897	0.19897	-0.44606	-0.8296974
ECA	0.82533	0.68118	0.48220	0.36339	5.816791
CLAY	0.86302	0.74481	0.06363	-0.27023	-0.6707968
TEMP	0.86456	0.74747	0.00266	0.29918	-0.5015374
SAND	0.86683	0.75139	0.00393	0.11648	-0.05746201
(CONSTANT)					46.05790

DEPTH 0-120cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
H2O	0.47540	0.22600	0.22600	-0.47540	-0.4931049
ECA	0.74455	0.55435	0.32835	0.33227	5.124568
CLAY	0.79017	0.62437	0.07002	-0.25747	-0.3013013
SAND	0.79194	0.62718	0.00280	0.27992	0.03955569
TEMP	0.79293	0.62873	0.00156	0.34909	0.2209059
(CONSTANT)					18.67087

Table 7.7 NOBLEFORD SALINITY SURVEY #7, APR 25-26, 1980 - HEDGEFIELD

* * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N   S U M M A R Y * * * * * * * * * * * *

DEPENDENT VARIABLE.. ECE

DEPTH 0-30cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.97424	0.94915	0.94915	0.97424	3.054374
TEMP	0.97860	0.95765	0.00850	-0.77407	-0.6700846
H2O	0.97974	0.95990	0.00225	0.83314	0.1402865
CLAY	0.97978	0.95996	0.00007	0.46162	0.02257714
(CONSTANT)					8.396655

DEPTH 0-60cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.94364	0.89046	0.89046	0.94364	4.008045
SAND	0.94633	0.89554	0.00508	-0.31858	0.3963890
CLAY	0.95402	0.91015	0.01461	0.43934	0.4596402
TEMP	0.95590	0.91375	0.00360	-0.73047	-0.5793501
H2O	0.95599	0.91391	0.00016	0.86379	0.1005741
(CONSTANT)					-19.32977

DEPTH 0-90cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.95330	0.90879	0.90879	0.95330	4.390849
SAND	0.95525	0.91250	0.00371	-0.45510	0.3686519
CLAY	0.96393	0.92917	0.01667	0.59946	0.3918727
TEMP	0.96448	0.93021	0.00104	-0.75435	-0.2966144
H2O	0.96458	0.93041	0.00019	0.88568	0.08467958
(CONSTANT)					-20.57991

DEPTH 0-120cm

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B
ECA	0.95297	0.90815	0.90815	0.95297	6.267160
CLAY	0.95540	0.91278	0.00463	0.68678	0.5514707
SAND	0.96674	0.93459	0.02181	-0.60562	0.4116765
H2O	0.96873	0.93843	0.00385	0.86613	-0.3157613
(CONSTANT)					-25.15670

when ECe' is predicted solely by ECa.

Table 7.8 Previous four-electrode study results.

Author	Date	r
Rhoades & Ingvalson	1971	0.99
Halvorson & Rhoades	1974	0.98 May measurements
		0.96 Aug. measurements
Halvorson & Rhoades	1976	0.955
Halvorson et al.	1977	0.92 - 0.99 (various soils in Montana, N. Dakota)
Read & Cameron	1979	0.84 - 0.98 (various soils in Saskatchewan)

All surveys on the Drainfield and Westfield sites had lower correlation coefficients than those from the Hedgefield survey, with multiple r values ranging from 0.87 down to 0.16 for the 0-120 cm measurement for the Drainfield survey of April, 1980. These values are considerably lower than those reported in the literature although Read and Cameron (1979) had two sites where correlation coefficients equalled 0.82 and a total of five sites where r values were less than 0.90. Tests for significance of multiple r were performed using tables by Snedecor (Sokal and Rohlf, 1973), and results show that the correlations for the Hedgefield, Westfield and the May survey at Drainfield were significant, at the p=0.01 level. Survey 3 (0-60 cm and 0-90 cm) and one depth in Survey 4 (0-30 cm) were considered significant at p=0.05 despite having r values below 0.70. The August and

April surveys at Drainfield were only significant for the 0-30 cm depth.

Several attempts were made to explain why three of the four surveys of the Drainfield site had low correlation coefficient values. Read and Cameron (1979) initially experienced low r values at two of their sites when comparing the variation of ECa with that of ECe. They attributed some of the unexplained variation to the wide range of textures present. By including variables for sand, clay, and moisture content along with ECa into a regression analysis, they improved the r values for the two sites to 0.84 and 0.82. Texture was not considered to be a factor in the low r values of Surveys 2, 3 and 4 (Tables 7.2, 7.3, and 7.4) since measurements were taken at the exact locations as those of Survey 1, where r values were comparable with those of all the sites studied by Read and Cameron (1979).

As mentioned previously, the small range of measured salinity values was also considered a factor in producing the lower r values for Surveys 1 to 6. Although a low salinity range would reduce the r values for all the correlations from the Drainfield and Westfield surveys, it was investigated to determine if it, or a low degree of variation in any of the other variables had any additional effect on Surveys 2, 3 and 4 that would contribute to the low r values. In order to standardize the variation of all the variable components of ECe' the coefficient of variation (CV) was determined for each variable. A linear regression

analysis was performed whereby the coefficient of variation for each of ECE, ECA, H2O, TEMP, SAND, and CLAY were individually compared to the final correlation coefficient (r) for each survey. Correlation coefficients for each regression analysis are shown in Table 7.9. These show no clear-cut evidence that the lack of variation in any of the variable components of ECe' is responsible for the low degree of correlation between ECe' and ECe.

Table 7.9
Correlation coefficients (r) for the coefficient of variation for each variable when compared with the correlation coefficients between ECe and ECe' from the seven surveys.

Variable	r
ECE	0.60
ECA	0.63
H2O	0.52
TEMP	0.11
SAND	-0.64
CLAY	0.47
SUM (of above)	0.63

It also appears that the cause of the low r values of Surveys 2, 3 and 4 may be time-dependent, since Survey 1 (Table 7.1) did not appear to be affected by low r values while Survey 4 was affected the most. In addition, the r values decrease with depth, which implies that the cause is depth-related as well. One explanation that incorporates reasons for both of these observations is that the subsurface drains installed in this field in 1977 and 1978

may have initiated a reduction of the salinity in the adjacent soil. A low correlation coefficient would result from some high ECe values corresponding to much lower ECe' values within the sampled population. This could result from the differences in sampling volumes between the core-method and the four-electrode method. A core sample could be taken from a local point of high salinity while the four electrode, with its larger sampling volume, would sample both the highly saline area as well as some adjacent areas of lower salinity that have been influenced by the presence of the subsurface drains. The probability of this occurrence would increase with depth, since the volume of the core sample would increase, for example, by a factor of 4 from a 0-30 cm measurement to a 0-120 cm measurement, whereas the four-electrode sampling volume would increase by a factor of 64 for the same two depths. Also, the subsurface drains would aid in reducing salinity over time, and account for an increase in the discrepancy between ECe and ECe' as time progressed.

To continue determining the reason for the low r values, the above explanation was tested based on the assumption that if the subsurface drains were exerting such an influence, the ECe' values predicted from Survey 2, 3 and 4 should be consistently lower than the measured ECe values, if the ECe' values are all calculated from the same set of regression equations. The set of equations that were chosen were those of Survey 1, and they can be considered as the

calibration equations that would be established before performing a year's work with the four electrode instrument. Table 7.10 shows averages of the measured ECe, the predicted ECe' as calculated from the equations of the May 1979 Drainfield survey, and the differences between the two sets of measurements for each depth of the four Drainfield surveys. From Table 7.10 it can be seen that there is a general trend toward ECe' underestimating ECe; however, at the 0-120 cm depth the differences were expected to be the greatest, and they are in fact, greatest at the 0-30 cm depth for Surveys 2 and 3. Although the test provides some support for the influence of the subsurface drains, it is by no means conclusive, and other factors may be influencing the low ECe' values. The data in Table 7.10 do show, however, that the trend toward ECe' underestimating ECe may result in some inaccuracies when using May, 1979, calibration equations for surveys performed at other times of the year.

Maps of salinity contours for the seven surveys are provided as Figures 7.10 through 7.23. Examination of the maps shows that generally there is good agreement between ECe contours and ECe' contours although in several cases, a local area of high or low salinity present on one map was not present on the other. The same contour interval of 4 mS/cm was used for all maps and it provided good resolution for the 0-30 cm and 0-60 cm depths, but a low degree of resolution for the 0-120 cm depth. An example is Survey 4

Table 7.10 Averages of measured (ECe) and predicted (ECe′) values of electrical conductivity for Drainfield, using only the May, 1979 calibration relationships.

	May 24, 1979											
	0 - 30 cm			0 - 60 cm			0 - 90 cm			0 - 120 cm		
	ECe	ECe′	Difference	ECe	ECe′	Difference	ECe	ECe′	Difference	ECe	ECe′	Difference
May 1979	15.8	15.8	0.0	15.6	15.6	0.0	14.8	14.8	0.0	14.0	14.0	0.0
Aug.1979	24.0	8.3	15.7	19.8	10.5	9.3	16.8	7.7	9.1	14.7	5.4	9.3
Sept.1979	22.4	9.5	12.9	20.1	12.3	7.8	17.5	13.0	4.5	15.6	16.5	-0.9
Apr. 1980	18.0	16.7	1.3	16.4	16.9	-0.5	14.9	14.3	0.6	13.8	13.1	0.7

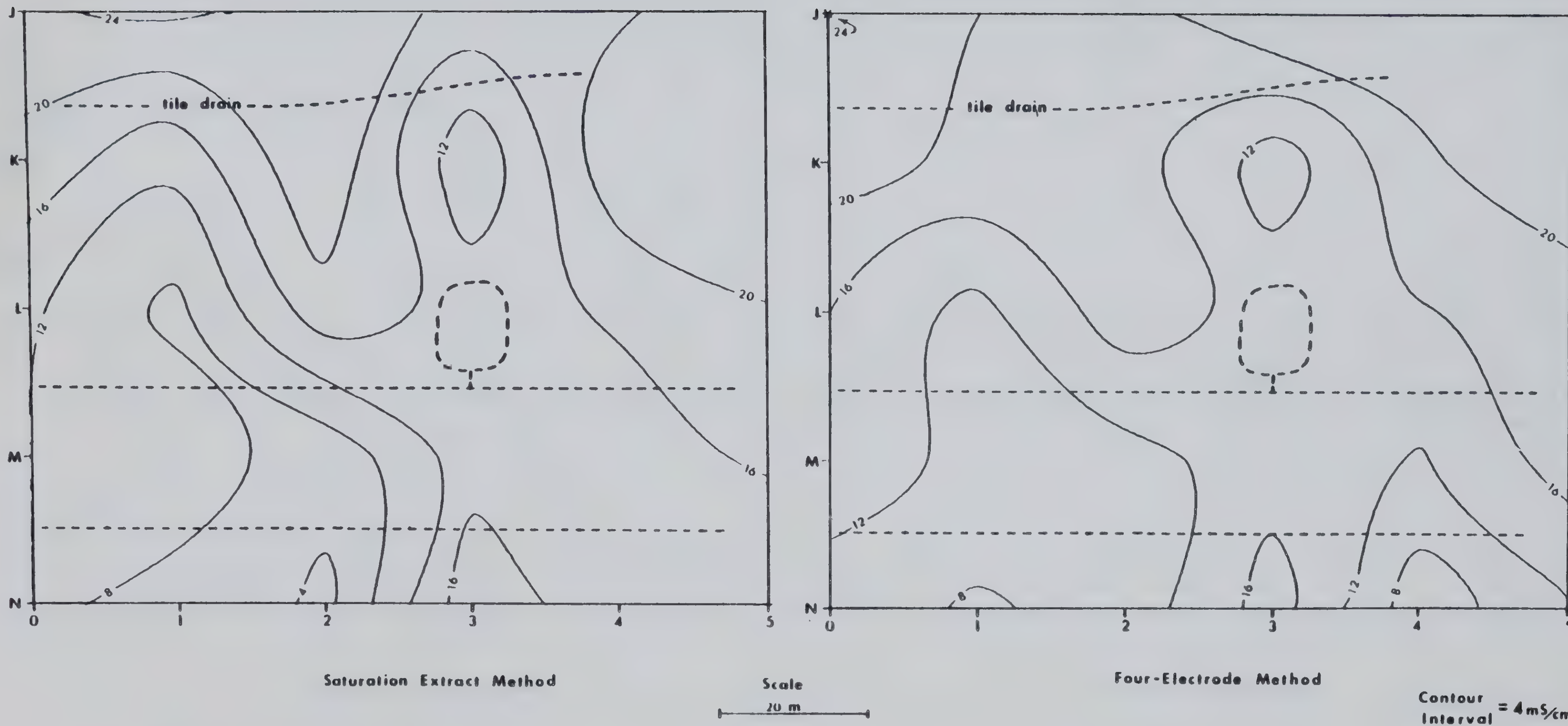


Figure 7.10 Salinity contour maps for Drainfield, 0-30 cm, May 24, 1979.

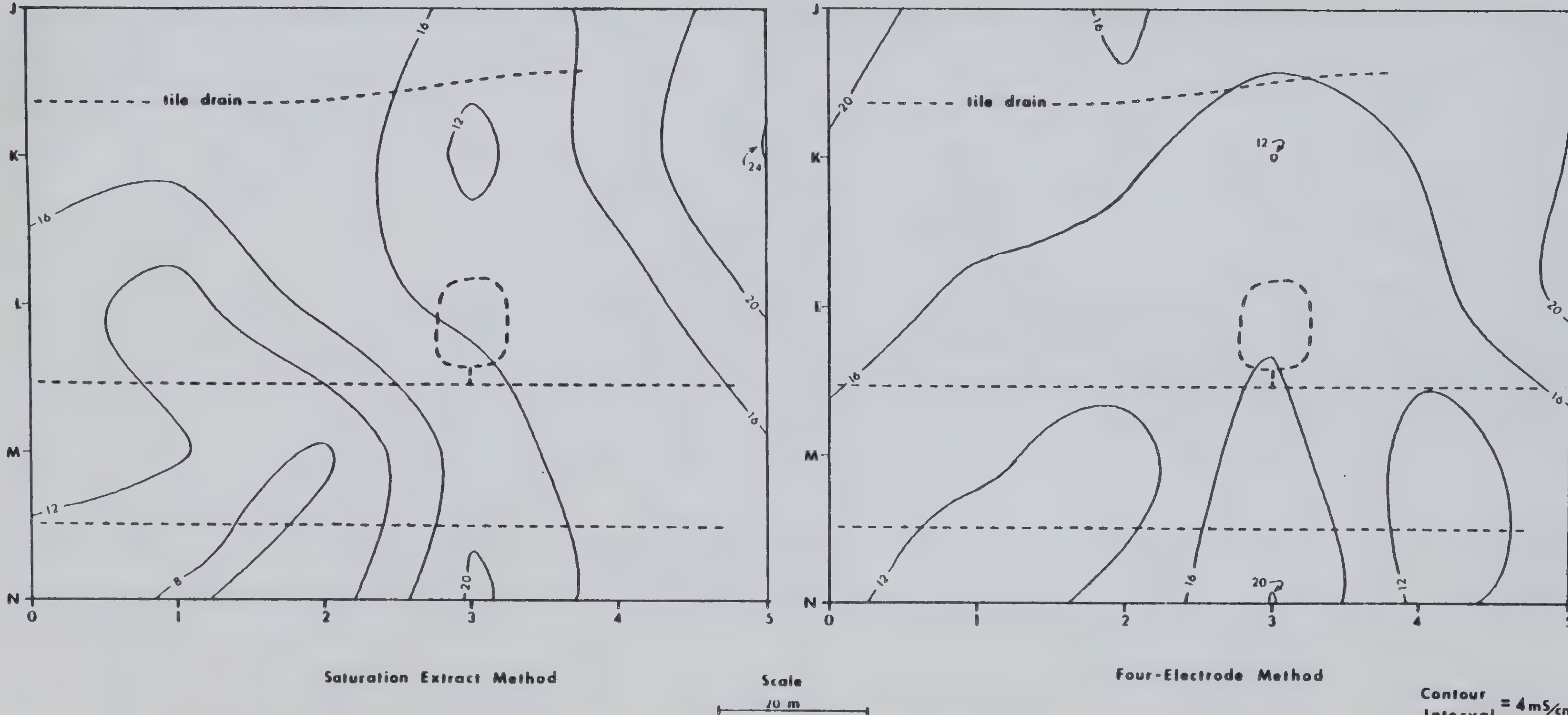


Figure 7.11 Salinity contour maps for Drainfield, 0-60 cm, May 24, 1979.

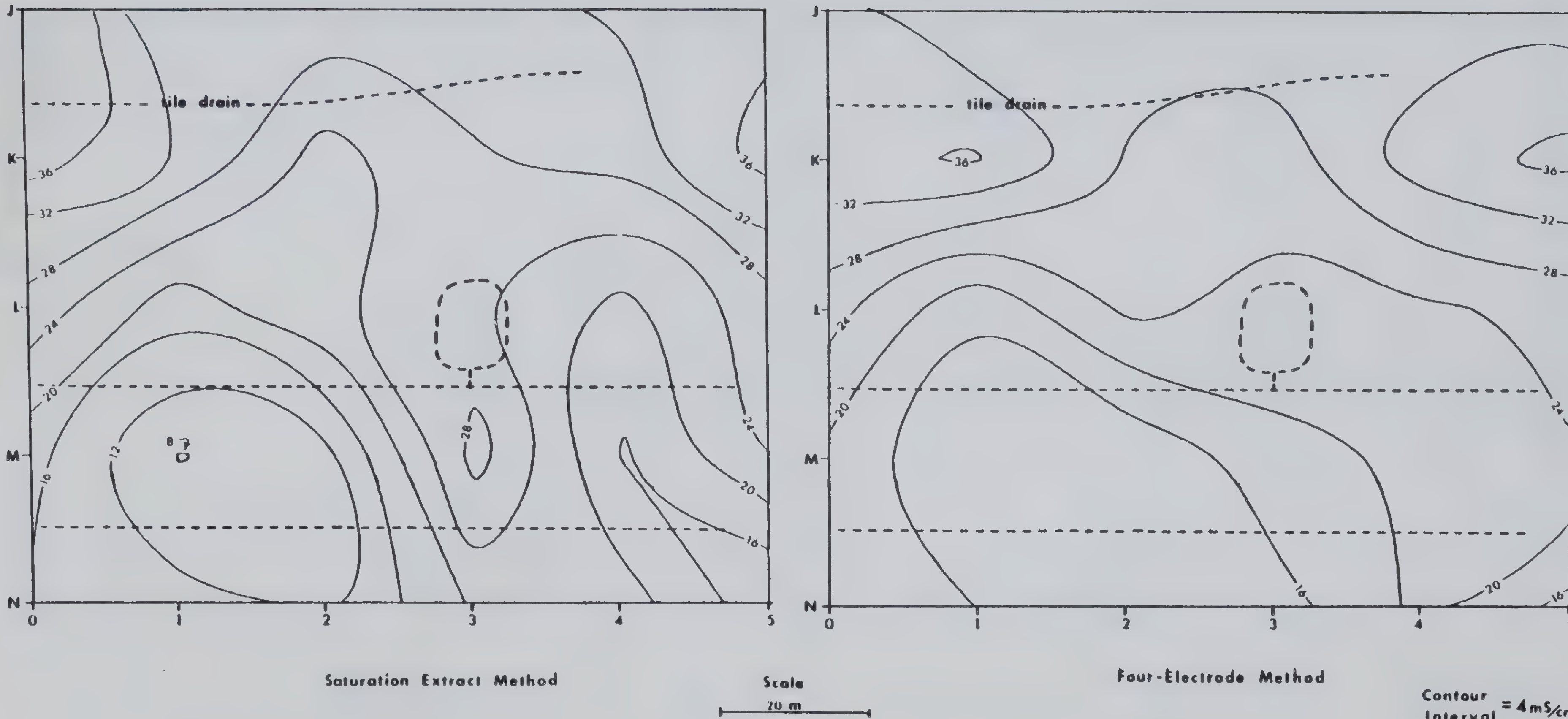


Figure 7.12 Salinity contour maps for Drainfield, 0-30 cm, August 21, 1979.

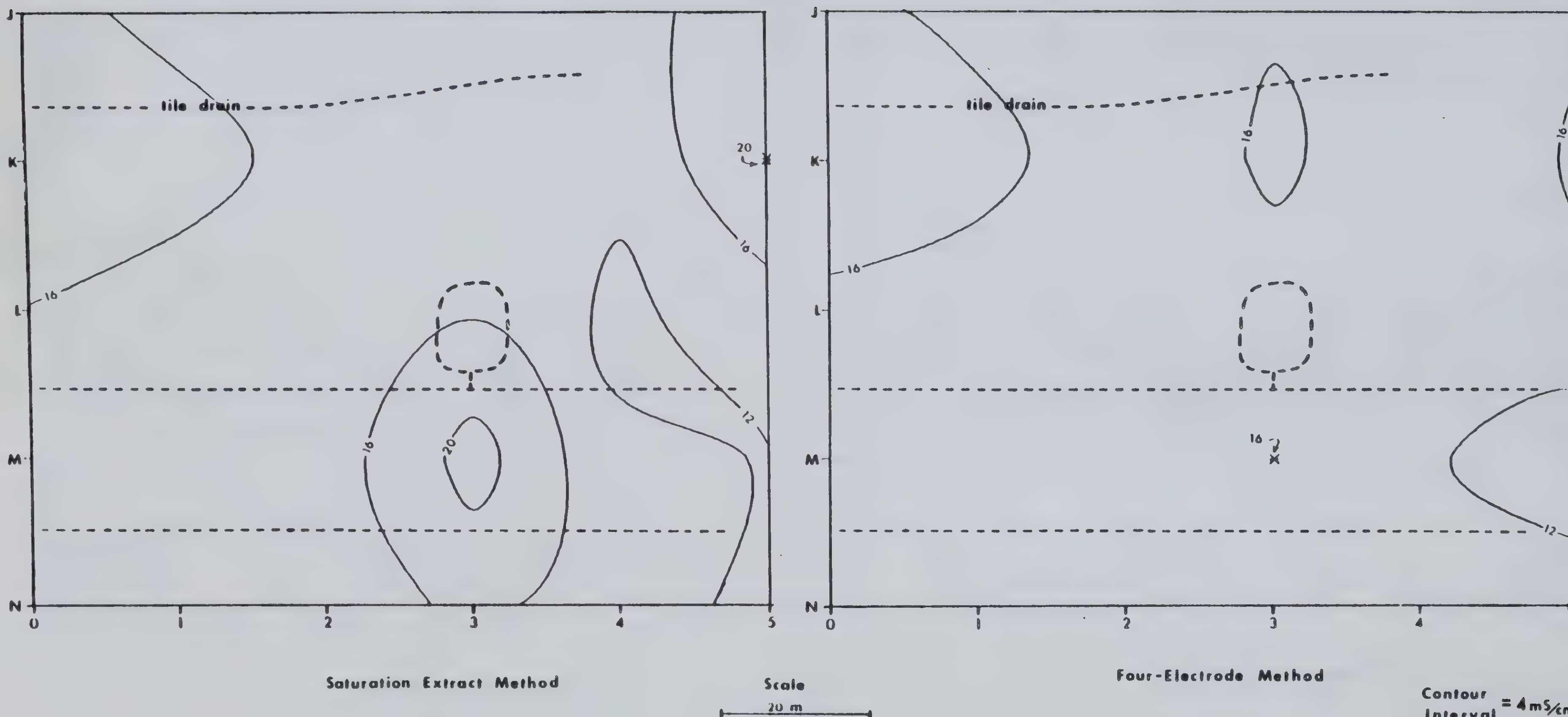


Figure 7.13 Salinity contour maps for Drainfield, 0-120 cm, August 21, 1979.

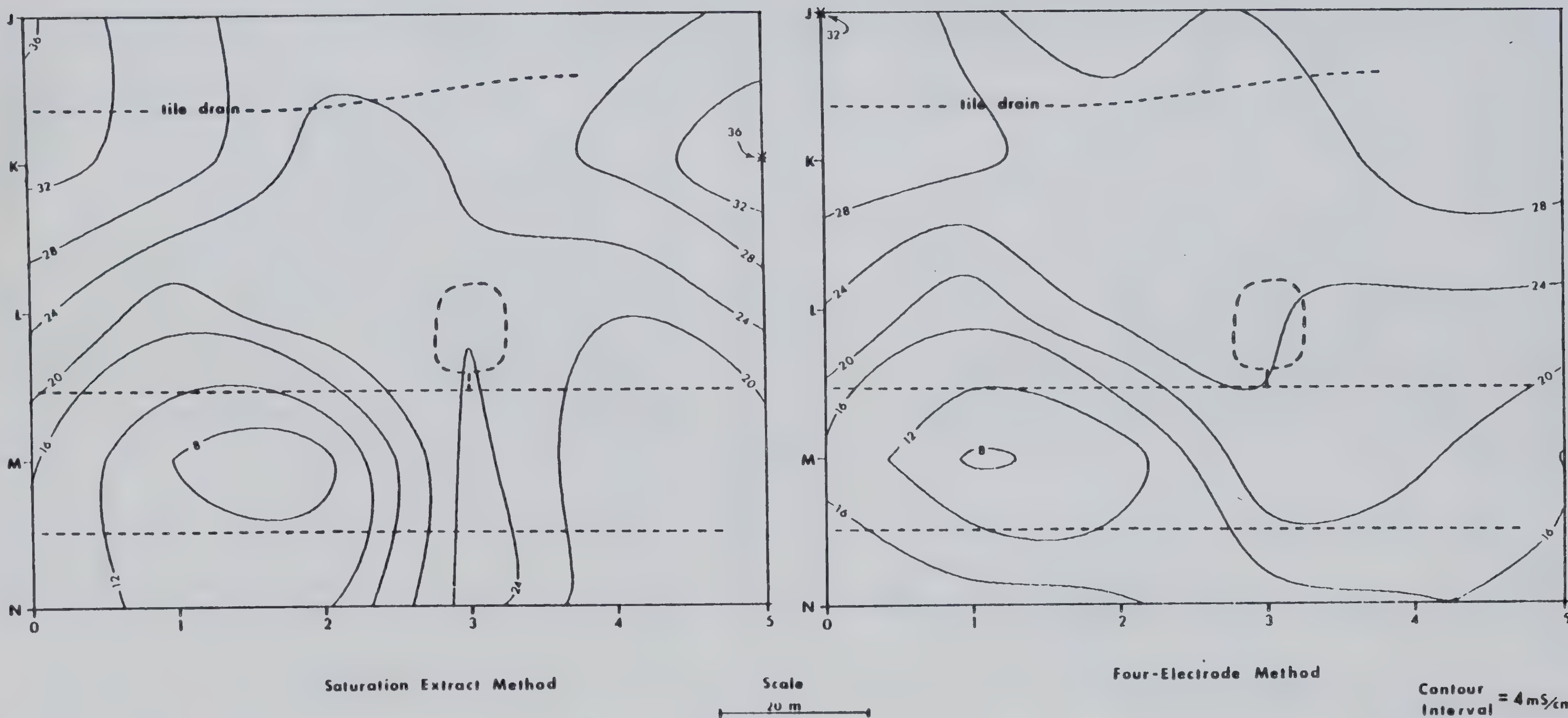


Figure 7.14 Salinity contour maps for Drainfield, 0-30 cm, September 30, 1979.

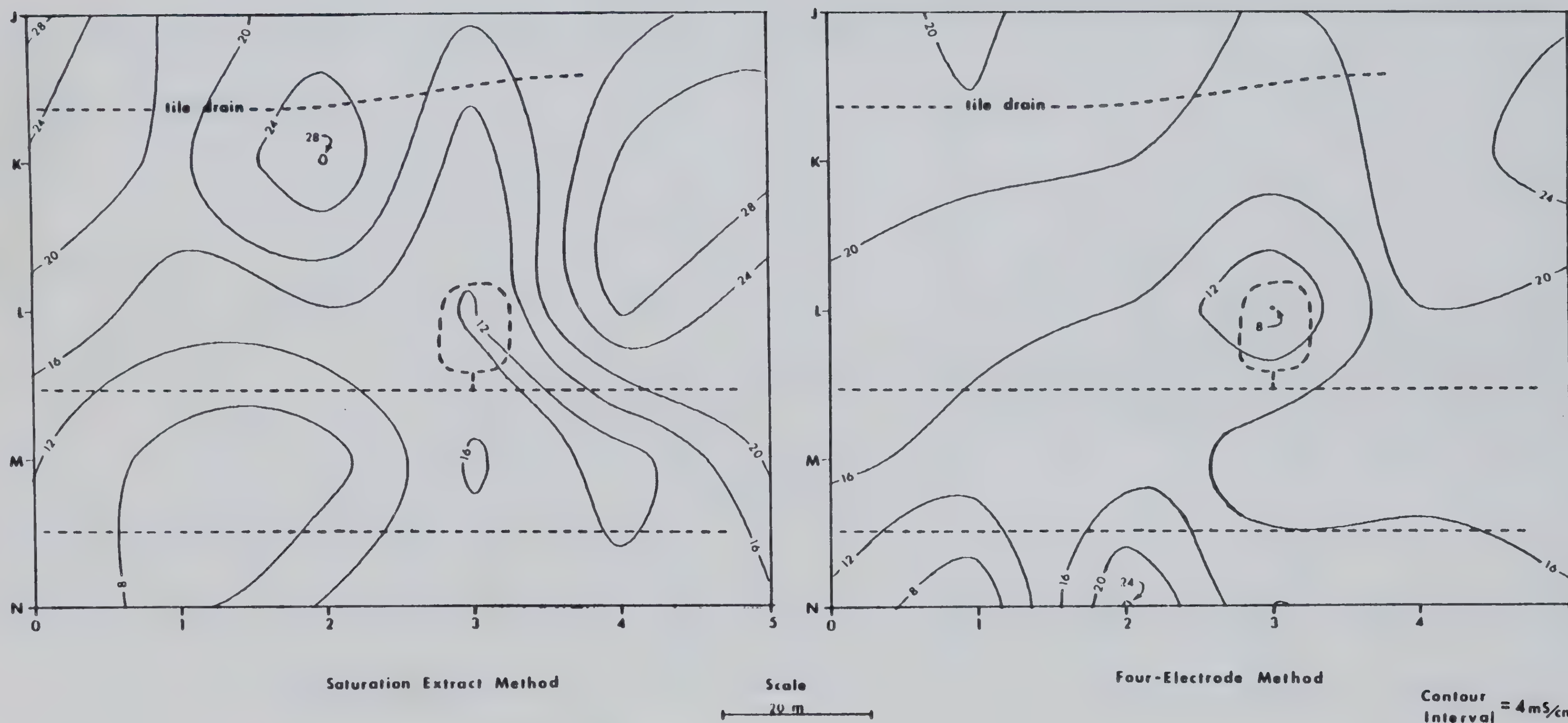


Figure 7.15 Salinity contour maps for Drainfield, 0-30 cm, April 25, 1980.

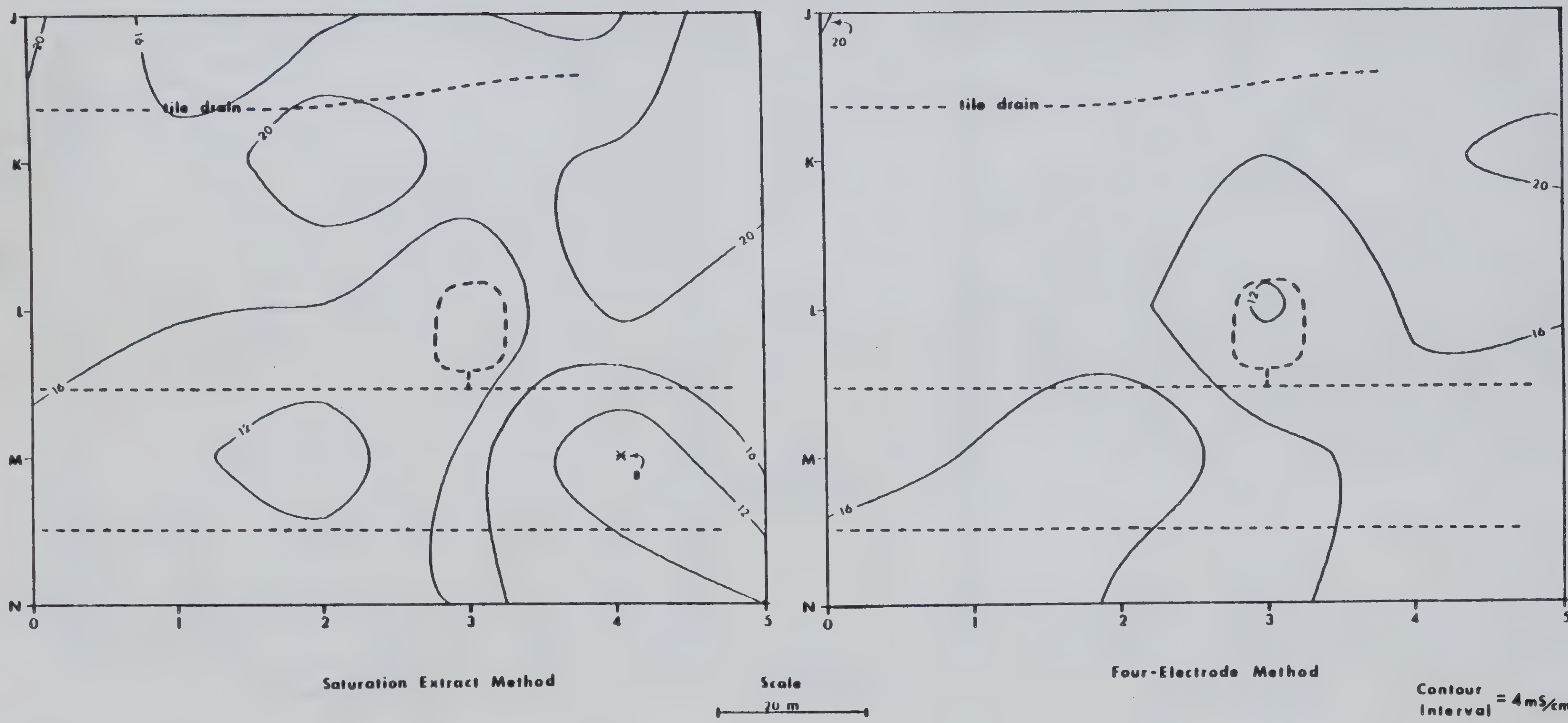


Figure 7.16   Salinity contour maps for Drainfield, 0-60 cm, April 25, 1980.

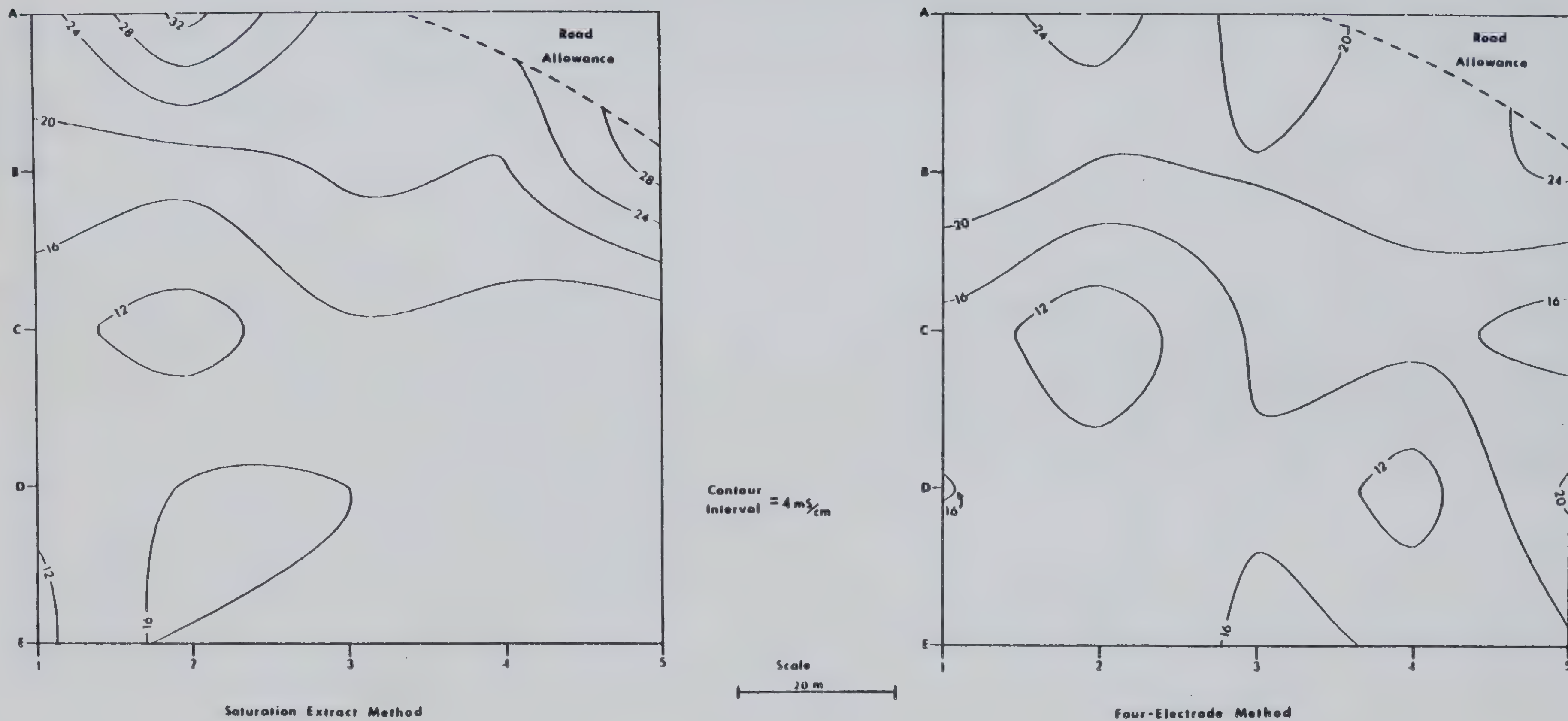


Figure 7.17 Salinity contour maps for Westfield, 0-30 cm, May 22, 1979.

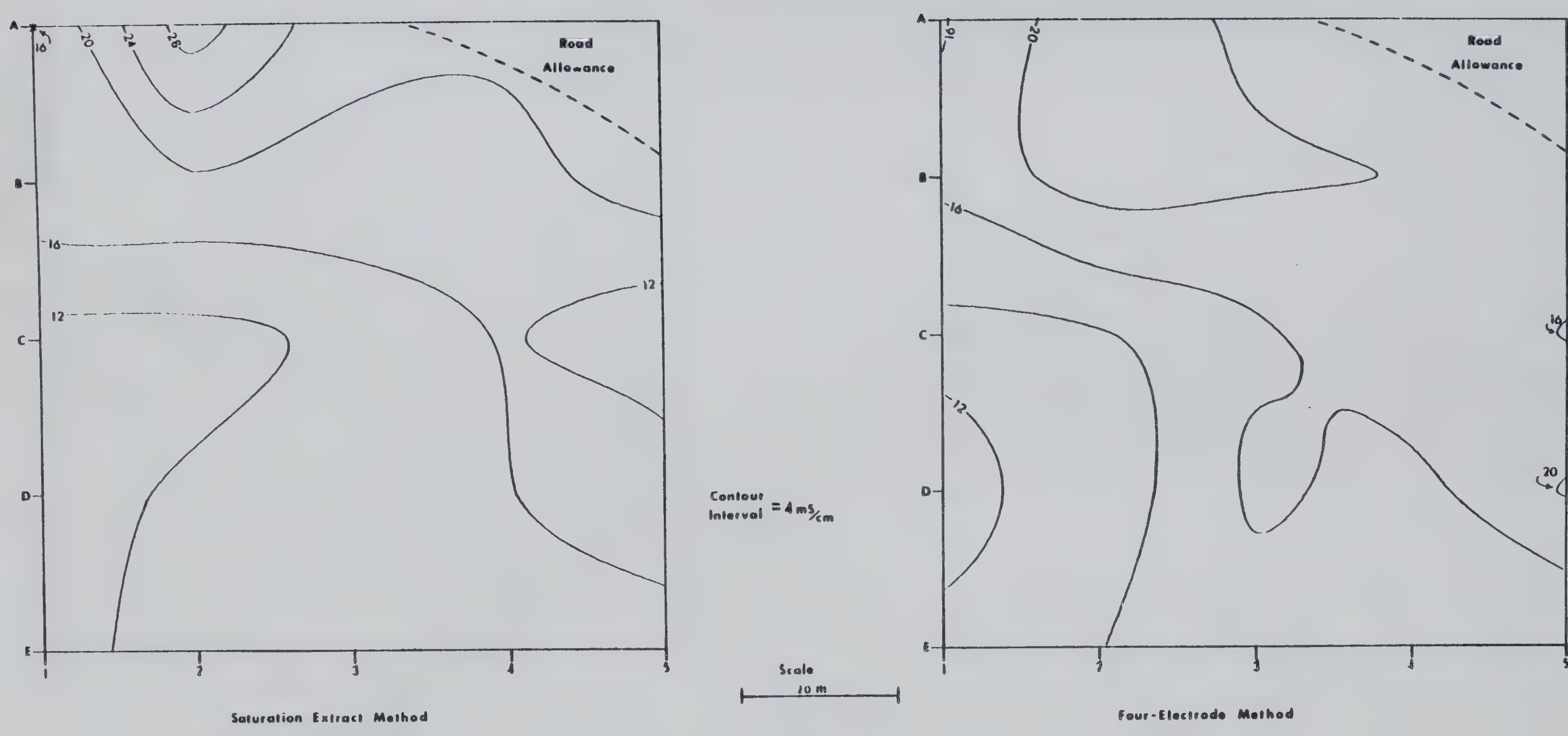


Figure 7.18 Salinity contour maps for Westfield, 0-90 cm, May 22, 1979.

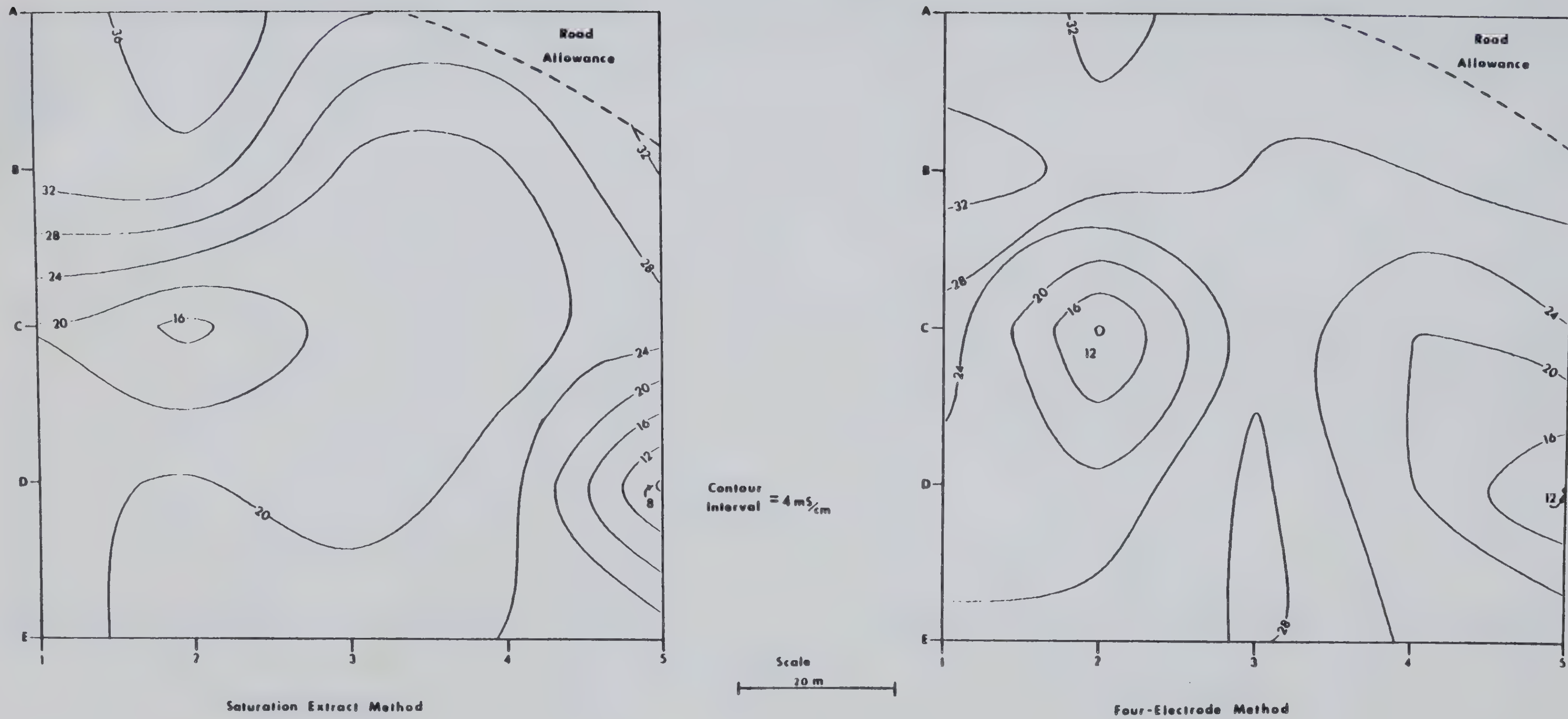


Figure 7.19 Salinity contour maps for Westfield, 0-30 cm, September 29, 1979.

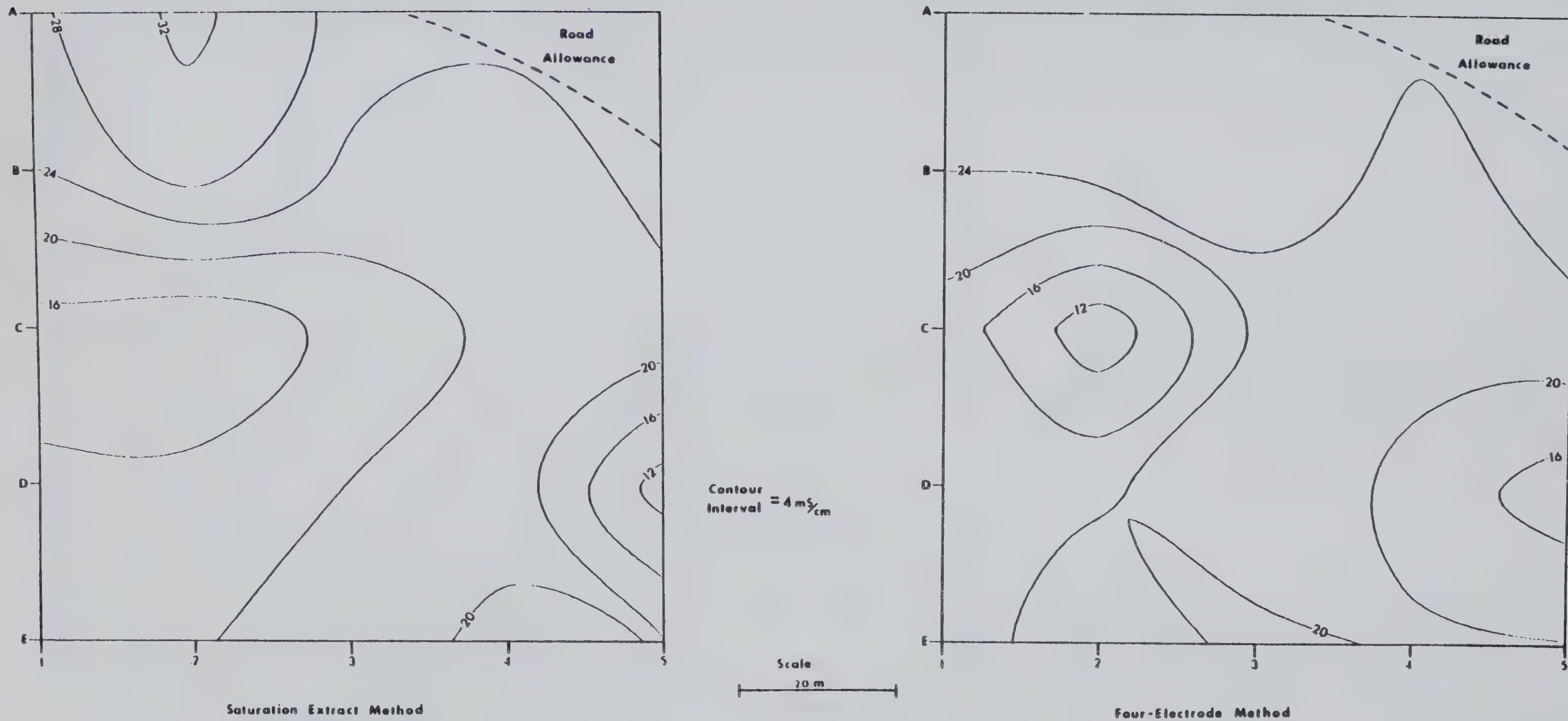


Figure 7.20 Salinity contour maps for Westfield, 0-60 cm, September 29, 1979.

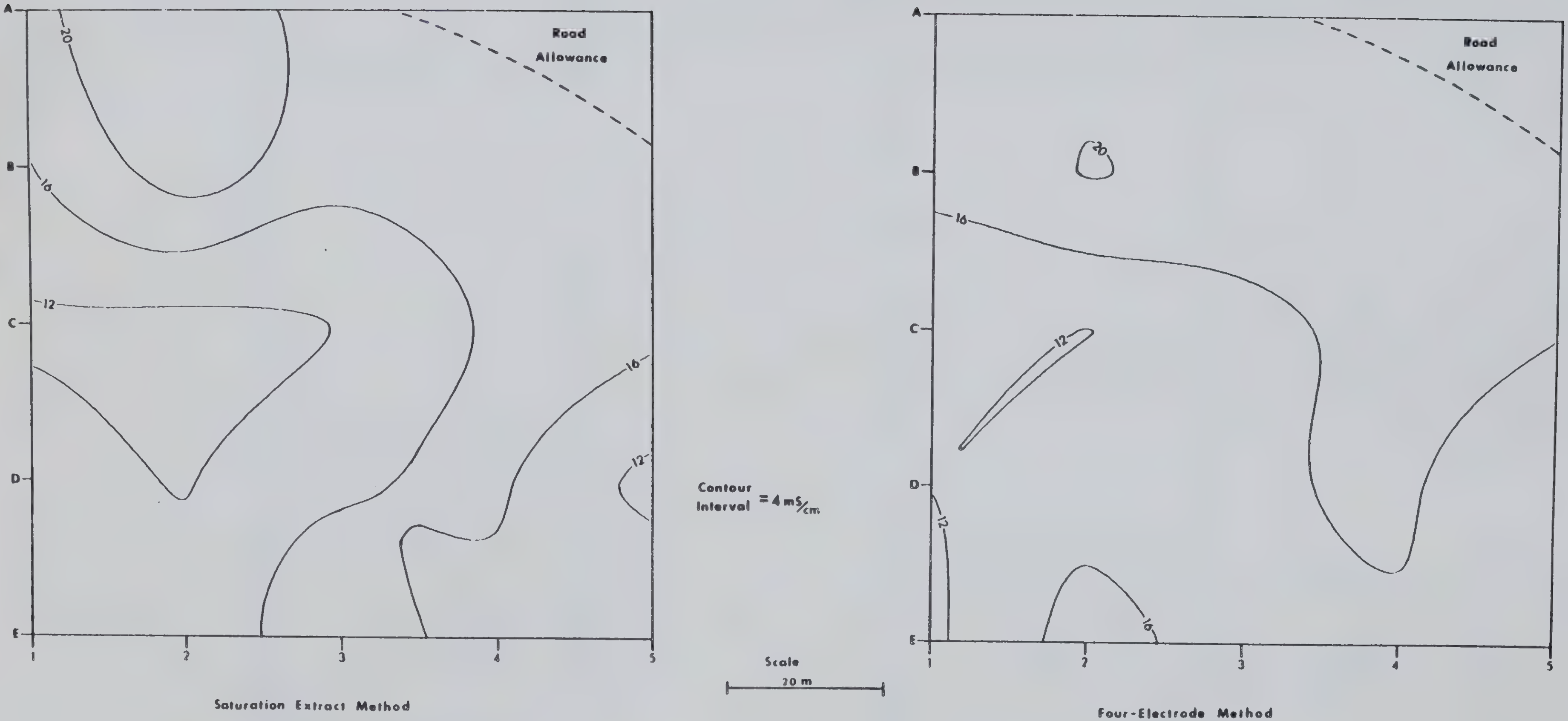


Figure 7.21 Salinity contour maps for Westfield, 0-120 cm, September 29, 1979.

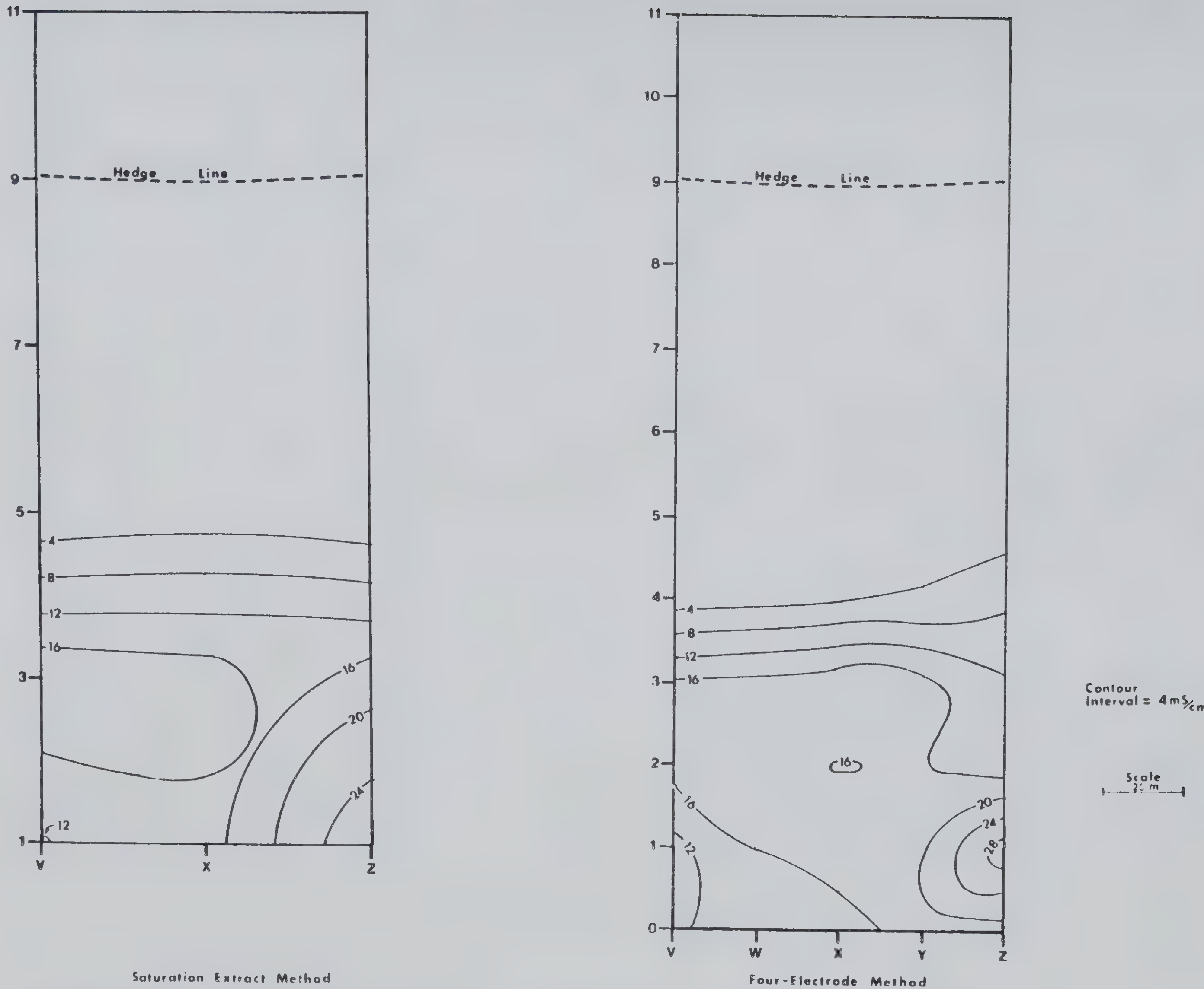


Figure 7.22 Salinity contour maps for Hedgefield, 0-30 cm, April 26, 1980.

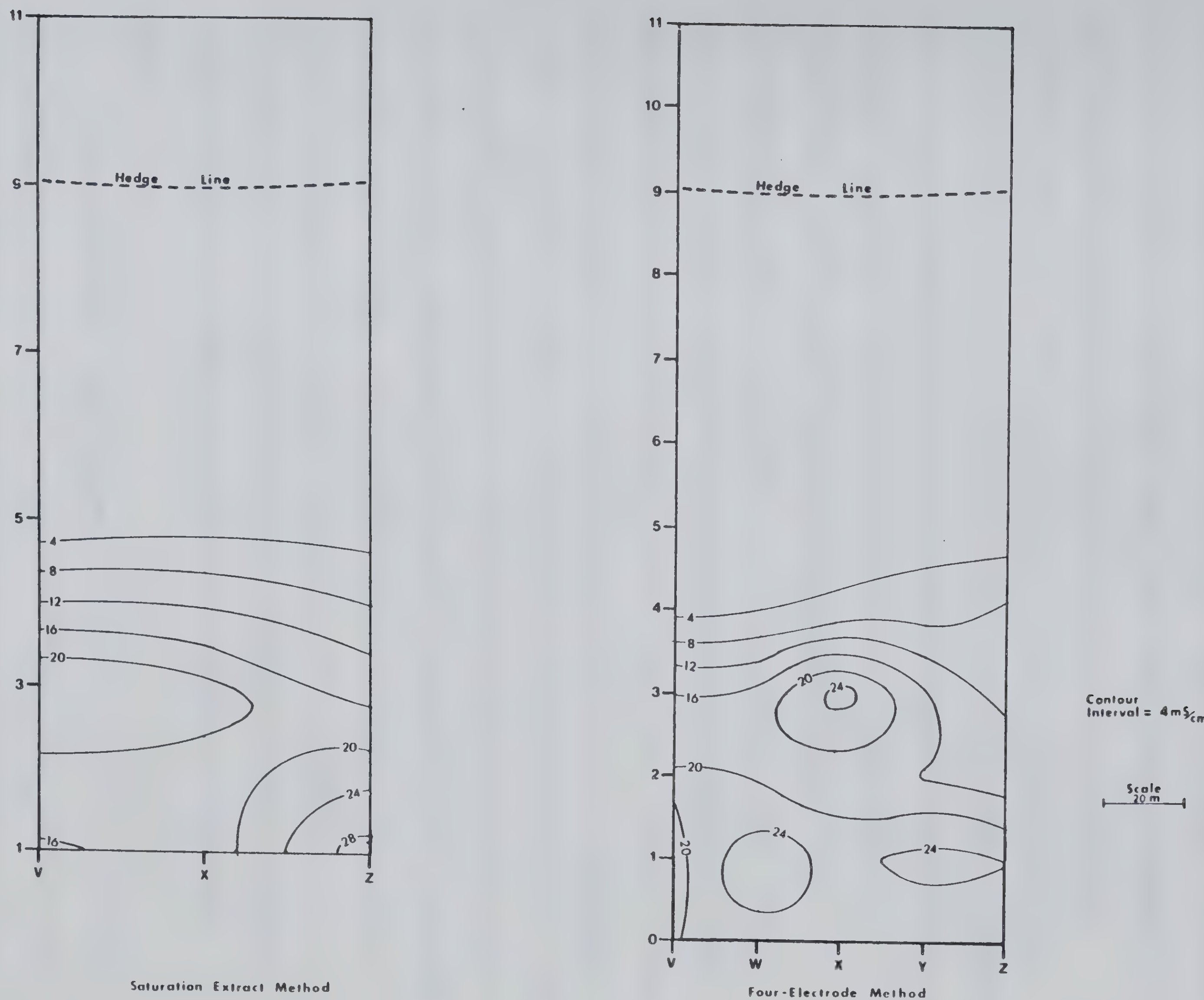


Figure 7.23 Salinity contour maps for Hedgefield, 0-60 cm, April 25, 1980.

(not shown), where the 0-120 cm ECe' map showed no contours at all. Generally, the maps of ECe' contours show a subdued relief compared to the ECe maps, and this can be explained by the greater sampling volumes of the four-electrode method. The maps show that areas of high and low salinity tend to occur in small pockets that show up on one gridpoint but are not detected on the adjacent gridpoint even with a grid as small as 20 m (see Figure 7.19). The highs at Drainfield tend to be found at the northwest and the northeast corners, which are the most upslope portions of the site, and at gridpoint M3. The lows are found in the southwest and southeast portions of the site. These extremes tend to persist with both depth and time. At the Westfield site, the high pocket is located around gridpoint A2 at the northern (upslope) edge of the site while a deep low pocket is seen on the September 1979 map at gridpoint D5. Although somewhat persistent with depth, this low pocket had been a local high area in the May survey of 1979. Another low at C2 and the high at A2 were detected by both surveys, although the low is very subdued on the ECe (saturation extract) maps.

The Hedgefield site survey shows that only a portion of the seep was mapped despite the fact that the entire area of burned out Kochia, a circular patch of approximately 30 m in diameter, was surveyed (see Figures 7.22 and 7.23). The maps of ECe and ECe' show excellent agreement, particularly concerning the upslope extent of the saline seep, as

delineated by the 4 mS/cm contour. Further comparisons are complicated by the fact that the ECe map involved measurements at a much lower density than the ECe' map. General agreement is found, however, for the high at gridpoint Z1. The Hedgefield maps, like the maps from the Drainfield and Westfield sites, show the persistence of local, isolated areas of high salinity, and the examination of these isolated spots gives evidence to a theory that the goundwater discharge is occurring at very small and randomly-dispersed areas.

The upslope portion of the Hedgefield maps was surveyed on a square grid of 10 m per side. It was anticipated that evidence of recharge activities from snow buildup upslope from the hedge could be detected as a result of finding low soil salinities there. Examination of the data in Appendix A shows that gridpoints immediately upslope from the hedge, where snowdrifting would most likely occur, do show some reduced electrical conductivity values. These values, however, are neither low enough nor consistent enough over the surveyed area to conclude that they are evidence of recharging processes.

7.2.2 Discrete Depth Measurements With the Four-Electrode Method

Calculation of ECx was performed using ECa data and equation 4.12 and entered into a stepwise multiple regression analysis along with measured discrete depth

values for ECe, field soil moisture content, soil temperature, percent sand and percent clay. The nature of equation 4.12 is such that any differences between ECe' as a function of ECa, and the measured ECe values are incorporated into the calculations for the next depth interval, and therefore the correlation between ECx and ECe is expected to decrease with depth. The multiple regression analysis indicated that this effect had taken place. In nearly all cases, the simple r value for ECx as a predictor of ECe is less than that for ECa in Tables 7.1 to 7.7 (pages 97 to 103). In many cases other measured variables such as soil moisture content or percent clay are more significant predictors. Even where correlation between ECa and ECe is high such as at the Hedgefield site, there is a noticeably lower r value for ECx.

7.2.3. Effect of Using Temperature Correction Factor (Ft)

The non-linear relationship between temperature and electrical conductivity (Ft) that was established by the U.S. Salinity Laboratory Staff (1954), was applied to ECa values before entering into a stepwise multiple regression analysis with values for ECe, soil moisture content, percent percent sand and percent clay. Results of the analysis showed that when compared to Tables 7.1 to 7.7, the temperature-corrected ECa value has a better simple correlation to ECe than does ECa. However, the overall multiple correlation of values show that ECe' is a better

predictor of ECe when temperature is entered as a linear function than if it is entered as the non-linear function Ft. The differences, though, are small and have little bearing on the overall comparison of the two mapping methods.

7.3 SALT MOVEMENT AT SURVEY AND MONITORING SITES

7.3.1 Salinity Fluctuations at the Survey Sites

The maps of all survey sites show that high and low concentrations of salts exist in very local areas of the sites. These isolated areas have been detected by both survey methods and often persist through the range of depths that were measured. In many cases they are so localized that they are detected at only one gridpoint, meaning that the twenty-metre grid spacing was not fine enough to fully measure the areal extent of these pockets. The four-electrode survey, with its larger sampling volume, showed many pockets were subdued in concentration compared to those measured by the saturation extract method. This indicates that the pockets may only be a couple of meters across. The maps also show that many of these areas exhibit considerable changes in salt concentration over the growing season. In Figure 7.24, salt concentration profiles have been drawn for cross-sections of maps of the Drainfield site and the Westfield site. The profiles demonstrate that large increases in soil salinity occur in the top 60 cm of the

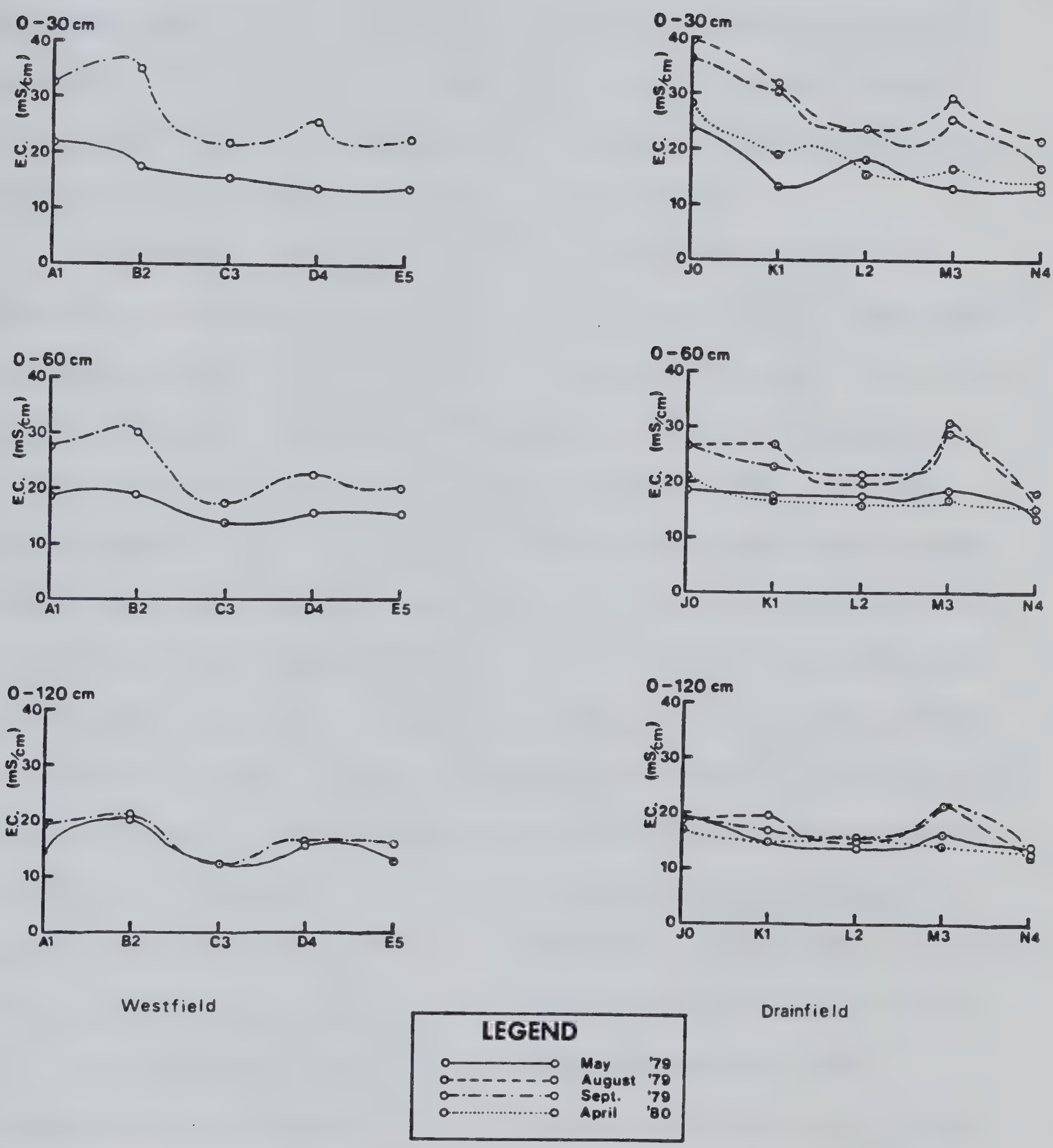


Figure 7.24 Cross-sections of the Westfield and Drainfield survey areas showing salinity fluctuations.

sites as the growing season progresses. Capillary flow from the water table, acting as the mode of salt transport, is therefore active to within 30 cm of the soil surface during late summer and fall. The profiles of the Drainfield maps show that salt concentrations are higher in August than in September. It is possible that the heavy rainfall event in late August acted to translocate the salts and reduce the concentrations during the month of September.

A prominent pocket of high soil salinity exists at point M3 on the Drainfield profile (Figure 7.24). The pocket increases in salt concentration considerably over the entire rootzone during August and September. At the 0-60 cm and 0-120 cm depths the pocket changes dramatically from May 1979 to April 1980 but the adjacent points were unaffected. A similar pocket exists at point D4 on the 0-30 cm and 0-60 cm depths of the Westfield site, but it does not stand out as prominently from the adjacent points as does the pocket at point M3. These points correspond to the highly localized areas of high salinity observed on the survey maps (Figures 7.10 to 7.21, pages 110 to 121). Points such as these are closer to the location of the groundwater discharge than are the surrounding portions of the saline seep-affected area.

It is possible that in the Nobleford basin the groundwater is moving vertically under hydraulic pressure through fractures or fissures in the overlying till. Such movement has been observed during the excavation to place subsurface drains at point L3, and it may be occurring at

other locations as well, giving rapid rise to salt concentrations at very local points. Fractures in southern Alberta tills are common and they can increase the saturated hydraulic conductivity of the till by as much as two orders of magnitude (Hendry, 1982). These fractures could be bringing groundwater discharge into the proximity of the rootzone and acting as point-sources for the saline seeps in this basin.

7.3.2 Salt Flux Calculations for the Monitoring Sites

Data acquired from the monitoring activities were combined to obtain a quantitive estimate of the salt movement from May to late August 1979 in the top 30 cm of soil in Sites A through F. One salinity sensor was available in 1978 and it was placed at location A. Values for salt mass as calculated from equation 6.1, volumetric moisture content, and electrical conductivity as calculated from ECa data using both the Hedgefield equations and those developed by Rhoades, as well as electrical conductivity measured by the salinity sensors are presented in the Appendix C. Average daily salt flux through the bottom face (100 cm^2) of a hypothetical cylinder representing the top 30 cm of soil, was calculated from the differences in salt mass divided by the number of days between successive monitoring events. By using a plane with an area of 100 cm^2, salt fluxes across this area, when expressed in grams, become numerically equal to tonnes/ha. The results are shown in Tables 7.11 and 7.12.

Table 7.11 Daily fluctuations of salt mass (g) at the 30 cm depth at the monitoring sites. Values are numerically equal to tonnes/ha.

* * * * * * * * * * * * * * * * * * LOCATION A * * * * * * * * * * * * * * * * * *

Year - 1978

Period	4-Electrode (Hedgfld Calibr)	4-Electrode (Rhoades Calibr)	Salinity Sensor	Soil %H20
June 20-26	-0.637	-0.823	-0.997	-1.4
June 27-July 4	0.154	0.451	-0.227	-1.3
July 5-14	0.292	0.580	0.723	0.9
July 15-20	No Data	No Data	0.144	-0.1
July 21-24	No Data	No Data	0.236	0.0
July 25-31	No Data	No Data	-0.998	-0.5
August 1- 9	No Data	No Data	-0.133	-0.4
August 10-14	No Data	No Data	0.507	-0.3
August 15-18	No Data	No Data	0.919	1.1
August 19-21	1.322	2.511	0.611	1.0

Year - 1979

Period	4-Electrode (Hedgfld Calibr)	4-Electrode (Rhoades Calibr)	Salinity Sensor	Soil %H20
May 29-June 4	-0.204	-0.187	No Data	1.5
June 5-11	0.398	0.904	No Data	-0.3
June 12-18	-0.107	-0.180	1.784	0.4
June 19-25	-0.353	-0.647	0.064	-1.2
June 26-July 4	0.060	0.151	0.277	-1.3
July 5- 9	-1.027	-1.629	0.404	-0.8
July 10-16	0.382	0.682	0.507	-0.6
July 17-23	0.629	1.276	-2.284	-1.9
July 24-30	-1.211	-2.527	-0.296	-0.1
July 31-August 8	No Data	No Data	-0.069	0.8
August 9-13	No Data	No Data	0.184	0.0
August 14-20	No Data	No Data	-0.052	-1.2
August 21-27	0.889	1.563	0.767	8.5

* * * * * * * * * * * * * * * * * * LOCATION B * * * * * * * * * * * * * * * * * *

Year - 1979

Period	4-Electrode (Hedgfld Calibr)	4-Electrode (Rhoades Calibr)	Salinity Sensor	Soil %H20
May 29-June 4	-0.338	-0.420	No Data	-3.1
June 5-11	0.364	0.601	No Data	5.8
June 12-18	-0.207	-0.201	-0.084	-4.2
June 19-25	-0.304	-0.480	-0.098	-3.7
June 26-July 4	-0.279	-0.571	-0.059	-2.0
July 5- 9	-0.164	0.156	0.004	-0.3
July 10-16	0.079	0.074	-0.004	-0.3
July 17-23	-0.030	0.004	-0.267	-1.0
July 24-30	-0.149	-0.452	-0.003	0.2
July 31-August 8	No Data	No Data	-0.047	0.0
August 9-13	No Data	No Data	0.062	0.1
August 14-20	No Data	No Data	-0.080	-1.0
August 21-27	0.589	0.942	-0.057	10.1

Table 7.12 Daily fluctuations of salt mass (g) at the 30 cm depth at the monitoring sites. Values are numerically equal to tonnes/ha.

* * * * * * * * * * * * * * * * * * LOCATION C * * * * * * * * * * * * * * * * * *

Year - 1979

Period	4-Electrode (Hedgfld Calibr)	4-Electrode (Rhoades Calibr)	Salinity Sensor	Soil %H2O
May 29-June 4	-0.206	-0.074	No Data	-1.6
June 5-11	-0.551	-0.408	No Data	-3.1
June 12-25	-0.076	-0.090	-0.251	-5.2
June 26-July 4	0.049	0.091	0.028	1.0
July 5- 9	0.253	0.458	-0.129	-2.5
July 10-18	-0.190	-0.513	-0.021	-1.4
July 19-23	0.000	-0.120	-0.062	-1.4
July 24-30	0.000	-0.122	0.014	0.1
July 31-August 8	No Data	No Data	-0.013	-0.8
August 9-13	No Data	No Data	0.020	0.2
August 14-20	No Data	No Data	-0.009	-0.5
August 21-27	No Data	No Data	No Data	No Data

* * * * * * * * * * * * * * * * * * LOCATION D * * * * * * * * * * * * * * * * * *

Year - 1979

Period	4-Electrode (Hedgfld Calibr)	4-Electrode (Rhoades Calibr)	Salinity Sensor	Soil %H2O
May 17-28	-0.290	-0.137	No Data	-4.3
May 29-June 4	-0.563	-1.174	No Data	-1.8
June 5-11	0.082	0.400	No Data	-1.0
June 12-18	1.404	2.922	0.259	-0.2
June 19-25	-1.119	-2.162	-0.004	-0.7
June 26-July 4	-0.558	-1.044	-0.297	-0.8
July 5- 9	0.022	-0.849	-0.622	-0.8
July 10-16	0.164	0.874	-0.141	-0.5
July 17-23	0.631	1.434	0.114	-0.3
July 24-30	-0.198	-0.467	-0.059	-0.2
July 31-August 8	No Data	No Data	-0.054	0.1
August 9-13	No Data	No Data	0.129	0.1
August 14-20	No Data	No Data	0.009	-1.3
August 21-27	0.789	1.489	1.712	10.4

* * * * * * * * * * * * * * * * * * LOCATION E * * * * * * * * * * * * * * * * * *

Year - 1979

Period	4-Electrode (Hedgfld Calibr)	4-Electrode (Rhoades Calibr)	Salinity Sensor	Soil %H2O
May 17-28	-0.113	-0.231	No Data	-0.5
May 29-June 4	-0.174	-0.360	No Data	-0.2
June 5-11	-0.120	-0.208	No Data	-0.5
June 12-18	0.271	0.568	0.504	0.7
June 19-25	-0.353	-0.676	0.524	-0.8
June 26-July 4	-0.231	-0.466	0.377	-0.2
July 5- 9	0.144	0.398	-0.167	-0.6
July 10-16	-0.104	-0.233	0.234	-0.1
July 17-23	0.381	0.773	0.530	0.1
July 24-30	No Data	No Data	0.533	0.1
July 31-August 8	No Data	No Data	0.161	-0.7
August 9-13	No Data	No Data	0.033	0.1
August 14-20	No Data	No Data	1.568	-0.2
August 21-27	0.309	0.538	-1.800	0.8

The daily salt flux data in Tables 7.11 and 7.12 show that the salinity, as derived from the four-electrode measurements, increases considerably during the period from August 21 to August 27, 1979. This occurs at all sites except Site C, where ponded water at the site made it inaccessible for measurement. The increase also corresponds to a large soil moisture increase which was brought about by the precipitation events of that week (see precipitation data, Figures 7.1 to 7.3, pages 81 to 83). Because of the addition of a large amount of relatively pure rainwater to the soil, leaching of the salts and, therefore a decrease in salt mass, or a negative salt flux, had been expected. The salinity sensor data at Site A and Site D show similar positive salt fluxes, but at Site E the sensors show a large negative flux.

During periods when soil moisture is low, bulk soil resistance will increase due to an increasing degree of tortuosity. It is widely believed that as soil moisture decreases, solute concentrations in pore-water will increase and act to somewhat offset the increasing tortuosity (Oosterveld et al, 1978; J. Rhoades, 1982, personal communication). Since the precipitation during the growing season of 1979 was below average, soil moisture contents were well below those measured at the sites during 1978. It is possible that the soil in the top 30 cm at each site was too dry for the increase in pore water concentrations to adequately compensate for the tortuosity, and as a result,

the four-electrode measurements were reflecting low moisture rather than low salt. Similarly, dry soils may remove moisture from the ceramic cup of the salinity sensor and similarly produce an apparent salinity decrease. An addition of moisture would then serve to lower soil resistances to more accurate levels, and this could be interpreted as a salinity increase. Further study would be necessary to prove this however.

7.4 SOIL CHEMICAL AND PHYSICAL DATA

Data for the ion analysis of the saturation extracts from the Drainfield surveys of September 1979, April 1980, and the Westfield survey of September 1979 are presented in Table 7.13. Also presented in Table 7.13 is the ion analysis for discharge water from the subsurface drain system at Drainfield in September of 1979.

The data show that the electrical conductivity and cation concentrations in the subsurface drain effluent are lower than those of the saturation extracts. The sodium adsorption ratios (S.A.R.) of the effluent are, however, similar to most of those measured from the soil samples. The saturation extracts and the drain effluent have similar cation ratios but considerably different concentrations, which demonstrates that salt accumulation in the soil is occurring by evapotranspiration of the groundwater.

Analysis of saturation extract data from individual soil samples shows that the highest ion concentrations exist

Table 7.13

Data from the chemical analysis of saturation extracts from Drainfield and Westfield soil samples, and the subsurface drain effluent from Drainfield.

Drainfield

Sept. 29-30, 1979						
Depth (cm)	E.C. (mS/cm)	Na^{+} (meq/L)	Ca^{+2} & Mg^{+2} (meq/L)	SO^{-2} (meq/L)	Cl^{-} (meq/L)	S.A.R.
0-30	22.4	221.7	152.0	339.8	12.4	25.4
30-60	17.7	175.5	84.1	243.4	8.4	27.1
60-90	12.5	117.7	54.7	160.4	6.0	22.5
90-120	10.1	86.7	46.8	124.2	4.7	17.9
April 25-26, 1980						
Depth (cm)	E.C. (mS/cm)	Na^{+} (meq/L)	Ca^{+2} & Mg^{+2} (meq/L)	SO^{-2} (meq/L)	Cl^{-} (meq/L)	S.A.R.
0-30	18.0	165.8	94.1	230.0	17.2	24.2
30-60	14.9	147.4	60.5	196.0	8.6	26.8
60-90	12.0	105.4	44.4	140.2	5.8	22.4
90-120	10.3	93.6	37.1	132.2	4.8	21.7

Westfield

Sept. 25, 1979						
Depth (cm)	E.C. (mS/cm)	Na^{+} (meq/L)	Ca^{+2} & Mg^{+2} (meq/L)	SO^{-2} (meq/L)	Cl^{-} (meq/L)	S.A.R.
0-30	25.3	229.6	211.4	408.6	16.2	22.3
30-60	16.8	154.2	105.3	247.4	8.8	21.2
60-90	12.5	102.1	76.4	168.6	5.0	16.5
90-120	8.9	68.8	49.7	110.4	3.1	13.8

Subsurface Drain

Sept. 28, 1979						
Depth (cm)	E.C. (mS/cm)	Na^{+} (meq/L)	Ca^{+2} & Mg^{+2} (meq/L)	SO^{-2} (meq/L)	Cl^{-} (meq/L)	S.A.R.
	11.0	100.0	36.0	No Data	No Data	23.6

in the most upslope (northerly) portions of Westfield and Drainfield. Sodium ion concentrations frequently exceeded 400 meq/L, while sulphate ion concentrations exceeded 500 meq/L in some of the upslope areas. The lowest ion concentrations were found in the most downslope portions of both study areas. Nitrate ion concentrations in the drain effluent averaged 122.3 meq/L for the period of October 12 to November 8, 1979.

Soil bulk density data for representative portions of the study areas are presented in Table 7.14 . The Shelby tube method presented very few operational problems during sampling, but compaction of samples can occur when the soil is wet, and result in a loss of accuracy when measuring bulk density. If, under wet soil conditions, the tube is pushed into the soil with care, compaction can be minimized. The method is an easy way to obtain minimally-disturbed samples at depth. Soil moisture contents, soil temperature and textural data for each survey is presented in Appendix C.

Table 7.14

Soil bulk density values of Shelby tube samples from the Nobleford and Lethbridge study areas.

LOCATION	DEPTH (cm)	DRY BULK DENSITY (g/cm^3)
Site B	3-15	1.52
	25-40	1.49
Site D	0-15	1.48
	20-40	1.40
	50-75	1.55
	80-110	1.65
Site E	0-15	1.44
	20-40	1.46
	55-85	1.49
Site F	0-25	1.29
	30-60	1.32
Westfield (A1)	0-15	1.44
	25-60	1.36
Drainfield (J3)	0-20	1.45
	25-40	1.42
Hedgefield (V1)	0-30	1.36
	40-65	1.41
	65-85	1.67

VIII. SUMMARY AND CONCLUSIONS

Dryland salinization is a process brought about by a combination of geologic, hydrologic and cultural factors. The mechanism of salinization is initiated by a change in any one or in combinations of these factors that results in an excess of moisture being available to translocate salts to areas within the rootzone. Changes in hydrologic or cultural factors are the most likely means of initiating salinization. Any change in meteorological conditions that would lead to excess moisture would be difficult to prove because of the relatively short period of time through which data has been collected. Cultural practices readily influence hydrologic conditions within the soil through changes in water use. The construction of ditches, roadways, water reservoirs, fences and windbreaks tend to prolong periods of water ponding and soil saturation, which in turn increases the probability of recharge. The cultural practice which is implicated as the main contributor to dryland salinization is the crop-summerfallow rotation system that has traditionally been used by farmers of the area. The time lag from initiation of excess moisture conditions until salinity outbreaks, the distances from recharge area to discharge areas which usually involves lands of different ownership, as well as the vague identification of recharge areas and groundwater flow patterns are problems that have delayed the understanding of salinization and saline seep initiation. They also lead to difficulties in convincing the

farming public to alter a system that has proven successful in producing crops in a semi-arid region for more than two generations.

The early detection of saline seeps would assist in the reduction of the problem since changes in cropping could be suggested when reclamation is still a simple procedure. Studies by several authors have shown that the four-electrode method of soil salinity measurement can provide a fast, economical and reliable means for saline seep delineation. This study agrees that the four-electrode method is an excellent tool for the type of surveys needed to detect encroaching saline seeps. It has a relatively low cost, and provides readings that can be interpreted directly in the field, and is easy enough to use that large areas involving several measurements can be surveyed in a relatively short period of time. The maps from the Hedgefield survey show that the four-electrode method can differentiate saline soils from non-saline soils such that saline seeps can be easily delineated from the unaffected areas.

The surveys have shown that the problem of salinization on the north slope of the closed basin near Nobleford is far more extensive than was first thought. They also show that crop response is a very poor indicator of the extent or intensity of salinization and, much like an iceberg, what shows on the surface is only a small fraction of what exists below. Encroaching saline seeps can exist, visibly

undetected, within the rootzone for long periods of time, increasing the need for regular surveys in areas susceptible to saline seep activity.

Saline seeps in the Nobleford basin are characterized by numerous locations where a small, localized area has electrical conductivities considerably higher than the surrounding areas. Even with a gridpoint spacing as close as 20 m, they are often detected at only one gridpoint and undetected at the adjacent ones. They are present at all three survey locations and appear to persist with time. It is believed that saline seeps in this basin have originated from these localized areas, which act as point-sources for salinization. Groundwater appears to have moved upward by hydrostatic pressure into or near the rootzone through randomly-distributed fissures in the till. This idea is supported by observations in 1978 of continuous flow, apparently vertical, less than 20 cm downslope from a subsurface drain. Presence of fractures and fissures in the till has been observed by other researchers in Alberta. More study would be needed, however, to confirm the presence or absence of this process.

The Westfield and Drainfield surveys show that when the range of soil salinity does not include non-saline soils, the correlation between four-electrode-predicted electrical conductivities and those measured from the saturation extract of soil samples was reduced. Correlations in the Drainfield surveys are further complicated by what appears

to be a differential reduction in soil salinity brought about by the presence of the subsurface drains. Attempts to prove this theory however, were inconclusive. Generally, the maps generated from the four-electrode measurements produced a subdued relief compared to those generated from the saturation extract measurements. This can be explained by the large differences in sampling volumes between the two methods.

Inclusion of the independent variables soil moisture content, soil temperature, and texture did not significantly influence the prediction of four-electrode-generated electrical conductivity if the range of soil salinity extends from saline to non-saline, as in the case of the Hedgefield survey. In such cases, electrical conductivities can be derived directly from ECa measurements. It should be noted, however, that the soils in this study did not have a wide range of textures. Where the salinity range was confined to more saline values only, such as at Drainfield or Westfield, the independent variables play a more prominent role in the correlation between the two methods. Soil moisture appears to be the variable having the greatest effect on the four-electrode prediction of electrical conductivity after the variable ECa has been considered. This supports the conclusions of Rhoades and Ingvalson (1971) and Halvorson and Rhoades (1974, 1976).

Due to the lack of a large data base for four-electrode measurements in Alberta, calibration equations should be

checked for every survey. This can be accomplished by taking a small but representative number of soil samples at each survey site and comparing saturation extract electrical conductivities to those derived by the four-electrode method. This should be done every time a survey is taken. This study has shown that large errors can result from applying equations from a spring calibration to survey data taken during the summer and autumn.

When sampling, it is recommended that more than one soil sample be taken at each desired point in order to compensate for the large volume of soil that the four electrode apparatus measures. It has been shown in this study that considerable variations in salinity can occur within a small area. It is also recommended that four-electrode measurements be taken when the electrodes are in contact with the mineral component of the soil, for best comparisons with saturation extract electrical conductivities from soil samples. Thick accumulations of organic material, such as straw layers or mulches, can increase resistivity unless proper contact with the mineral portion of the soil is made.

Maps separating saline seep-affected areas from non-affected areas can be generated from ECa data alone, with the accuracy comparable to those generated from saturation extract data. Maps from both methods have delineated isolated pockets of high and low salinity that often persist with depth and time. Generally, time of year,

and variations in soil moisture and soil temperature did not affect the accuracy of the maps, since the variation in soil salinity was far more influential. Since this study was performed on soils with a clay-loam or finer texture, variations in soil moisture and soil temperature may have a much greater effect in coarse-textured soils. Soil moisture data from the Hedgefield survey show that variations in the soil moisture content within that survey area in the spring are as great as soil moisture variations encountered at Westfield from spring to autumn of 1979. This indicates that soil moisture content variations may not be detrimental to the separation of saline areas from non-saline areas. Since saline seep-affected areas tend to have wetter soil moisture conditions for longer periods of time than the adjacent unaffected areas, the variations actually tend to magnify differences between saline and non-saline soils when measured with the four-electrode method.

As a soil dries, the effect of the reduced soil moisture content is to increase electrical resistance through the soil. Since dissolved solids will tend to concentrate in the remaining soil water during periods of drying, it was thought that the decreased resistance of the more saline residual water would tend to offset the increased resistance experienced by having a lower number of pores filled with water. However, larger pores empty first in a drying soil, and electrical conductance must occur through interconnected micropores, which greatly increases

the tortuosity factor. Data from the monitoring sites show trends towards an overall decreased electrical resistance as a soil loses moisture. As a result, measurement of electrical conductivity by the four-electrode method may result in greater error if the soil is dry.

The results of this study show that there is some promise for salinity surveys with the four-electrode method when significant moisture and temperature variations exist within the soil. This in turn, means that surveys can be performed during all frost-free periods of the year, rather than just in the early spring. It would be practical to conduct salinity surveys in the late autumn and winter, after crops have been harvested; however, more information will be needed before the four-electrode method can be recommended for use during these times.

The four-electrode method can be used as a rapid, economical, and non-destructive means of determining soil salinity. Its application however, must be kept within certain limits. The method appears to be most suitable for separating saline soils from non-saline soils. When it is used to determine the degree of salinity, parameters such as soil moisture, texture, and soil temperature become more influential. Therefore, care must be taken when interpreting the data for this purpose.

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X. APPENDICES

APPENDIX A

NOBLEFORD SALINITY SURVEY #1, MAY 24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm				
J0	23.700	5.455	7.218	26.20	12.50	29.70	19.60
J1	24.900	4.539	5.858	27.50	13.50	27.60	19.30
J2	22.700	3.739	5.014	28.70	12.00	26.90	19.30
J3	18.900	5.569	7.276	27.40	13.00	24.10	21.90
J4	19.300	4.955	6.319	29.00	14.00	32.40	20.00
K1	13.200	4.829	5.868	26.00	16.00	29.40	18.00
K2	23.700	4.175	5.324	23.50	14.00	30.30	20.40
K3	8.700	2.177	2.646	16.30	16.00	42.10	20.90
K4	23.200	4.418	5.509	26.80	15.00	34.40	20.50
K5	23.700	6.059	7.363	21.90	16.00	26.00	19.90
L1	7.000	1.932	2.524	24.00	13.00	30.00	19.10
L2	18.400	3.669	4.855	24.00	12.50	32.10	23.00
L4	16.500	3.356	4.331	24.00	13.50	35.40	18.10
L5	19.900	3.607	4.712	28.60	13.00	30.10	22.20
M1	10.800	1.972	2.515	24.50	14.00	32.00	22.20
M2	5.100	1.907	2.432	23.40	14.00	33.60	19.80
M3	14.200	3.523	4.336	21.80	15.50	26.50	20.50
M4	14.500	2.171	2.836	24.00	13.00	29.70	19.60
M5	16.600	3.972	5.126	25.50	13.50	26.50	20.20
N1	6.200	1.778	2.217	21.00	15.00	17.20	19.99
N2	3.400	2.134	2.661	23.10	15.00	25.60	18.80
N3	18.900	4.610	5.602	22.50	16.00	26.80	19.10
N4	12.900	1.364	1.637	21.30	16.50	25.80	18.70
N5	12.400	3.152	3.784	19.20	16.50	29.30	18.00
			Depth 0-60cm				
J0	18.450	4.481	6.195	25.40	10.75	38.95	18.80
J1	18.650	4.107	5.539	27.85	11.75	35.35	19.90
J2	19.750	3.132	4.419	28.50	10.00	36.00	17.70
J3	14.850	4.407	6.016	27.30	11.25	24.10	21.60
J4	16.650	3.806	5.164	28.90	11.50	40.45	18.35
K1	17.400	4.385	5.625	29.50	13.75	24.60	19.50
K2	19.150	3.785	5.200	26.55	11.00	26.55	21.80
K3	10.650	2.041	2.737	19.85	12.00	38.45	19.90
K4	18.400	3.600	4.915	28.35	11.25	37.80	20.60
K5	24.300	4.451	5.890	24.45	12.50	28.35	20.15
L1	10.300	3.375	4.579	26.75	11.50	26.80	20.15
L2	17.500	3.454	4.807	25.70	10.50	28.15	23.30
L4	14.050	2.978	4.091	25.60	11.00	26.90	19.80
L5	20.750	4.806	6.561	29.15	11.25	23.25	20.00
M1	12.400	2.828	3.814	25.80	11.75	23.60	21.15
M2	7.500	1.920	2.605	23.80	11.50	33.65	20.45
M3	18.450	4.245	5.446	24.40	13.75	20.95	22.90
M4	13.050	2.178	2.992	24.65	11.00	22.60	22.00
M5	15.600	3.185	4.321	26.35	11.50	19.45	23.85
N1	7.500	2.407	3.145	24.50	13.00	15.45	22.00
N2	10.000	3.022	3.999	25.70	12.50	20.30	21.10
N3	20.800	4.582	5.878	23.90	13.75	21.00	18.90
N4	13.700	2.640	3.387	24.40	13.75	19.90	21.20
N5	15.100	2.724	3.494	21.30	13.75	25.20	17.40

NOBLEFORD SALINITY SURVEY #1, MAY 24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm				
J0	23.700	5.455	7.218	26.20	12.50	29.70	19.60
J1	24.900	4.539	5.858	27.50	13.50	27.60	19.30
J2	22.700	3.739	5.014	28.70	12.00	26.90	19.30
J3	18.900	5.569	7.276	27.40	13.00	24.10	21.90
J4	19.300	4.955	6.319	29.00	14.00	32.40	20.00
K1	13.200	4.829	5.868	26.00	16.00	29.40	18.00
K2	23.700	4.175	5.324	23.50	14.00	30.30	20.40
K3	8.700	2.177	2.646	16.30	16.00	42.10	20.90
K4	23.200	4.418	5.509	26.80	15.00	34.40	20.50
K5	23.700	6.059	7.363	21.90	16.00	26.00	19.90
L1	7.000	1.932	2.524	24.00	13.00	30.00	19.10
L2	18.400	3.669	4.855	24.00	12.50	32.10	23.00
L4	16.500	3.356	4.331	24.00	13.50	35.40	18.10
L5	19.900	3.607	4.712	28.60	13.00	30.10	22.20
M1	10.800	1.972	2.515	24.50	14.00	32.00	22.20
M2	5.100	1.907	2.432	23.40	14.00	33.60	19.80
M3	14.200	3.523	4.336	21.80	15.50	26.50	20.50
M4	14.500	2.171	2.836	24.00	13.00	29.70	19.60
M5	16.600	3.972	5.126	25.50	13.50	26.50	20.20
N1	6.200	1.778	2.217	21.00	15.00	17.20	19.99
N2	3.400	2.134	2.661	23.10	15.00	25.60	18.80
N3	18.900	4.610	5.602	22.50	16.00	26.80	19.10
N4	12.900	1.364	1.637	21.30	16.50	25.80	18.70
N5	12.400	3.152	3.784	19.20	16.50	29.30	18.00
			Depth 0-60cm				
J0	18.450	4.481	6.195	25.40	10.75	38.95	18.80
J1	18.650	4.107	5.539	27.85	11.75	35.35	19.90
J2	19.750	3.132	4.419	28.50	10.00	36.00	17.70
J3	14.850	4.407	6.016	27.30	11.25	24.10	21.60
J4	16.650	3.806	5.164	28.90	11.50	40.45	18.35
K1	17.400	4.385	5.625	29.50	13.75	24.60	19.50
K2	19.150	3.785	5.200	26.55	11.00	26.55	21.80
K3	10.650	2.041	2.737	19.85	12.00	38.45	19.90
K4	18.400	3.600	4.915	28.35	11.25	37.80	20.60
K5	24.300	4.451	5.890	24.45	12.50	28.35	20.15
L1	10.300	3.375	4.579	26.75	11.50	26.80	20.15
L2	17.500	3.454	4.807	25.70	10.50	28.15	23.30
L4	14.050	2.978	4.091	25.60	11.00	26.90	19.80
L5	20.750	4.806	6.561	29.15	11.25	23.25	20.00
M1	12.400	2.828	3.814	25.80	11.75	23.60	21.15
M2	7.500	1.920	2.605	23.80	11.50	33.65	20.45
M3	18.450	4.245	5.446	24.40	13.75	20.95	22.90
M4	13.050	2.178	2.992	24.65	11.00	22.60	22.00
M5	15.600	3.185	4.321	26.35	11.50	19.45	23.85
N1	7.500	2.407	3.145	24.50	13.00	15.45	22.00
N2	10.000	3.022	3.999	25.70	12.50	20.30	21.10
N3	20.800	4.582	5.878	23.90	13.75	21.00	18.90
N4	13.700	2.640	3.387	24.40	13.75	19.90	21.20
N5	15.100	2.724	3.494	21.30	13.75	25.20	17.40

NOBLEFORD SALINITY SURVEY #1, MAY 24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-90 cm				
J0	19.170	4.240	6.099	25.27	9.17	44.30	17.40
J1	16.570	3.601	5.056	27.73	10.17	40.47	19.27
J2	16.770	2.856	4.179	27.87	8.50	41.70	17.17
J3	12.800	4.240	6.005	26.60	9.83	30.13	20.13
J4	14.530	3.064	4.356	29.10	9.67	45.27	17.50
K1	15.370	3.699	4.998	29.20	11.67	22.20	20.03
K2	16.630	3.238	4.738	26.83	8.50	22.63	22.33
K3	9.630	2.290	3.282	21.80	9.33	40.33	19.30
K4	15.930	2.908	4.236	28.53	8.67	43.93	19.30
K5	20.130	3.653	5.107	24.97	10.33	34.10	19.00
L1	12.330	3.163	4.422	26.63	10.33	24.50	21.93
L2	14.970	3.118	4.583	25.37	8.33	24.37	24.33
L4	12.030	2.728	3.974	27.10	8.67	23.87	21.53
L5	19.000	4.150	5.900	28.23	9.67	25.13	19.47
M1	13.530	3.054	4.270	24.70	10.33	21.43	21.13
M2	9.470	2.053	2.896	24.10	10.00	31.50	19.47
M3	17.700	4.281	5.714	24.33	12.17	19.57	22.93
M4	12.370	2.504	3.547	23.87	9.83	21.90	21.33
M5	13.600	2.947	4.138	25.27	10.17	18.33	23.93
N1	10.670	2.947	4.015	24.67	11.33	15.87	21.85
N2	13.030	3.215	4.454	25.37	10.67	22.83	21.90
N3	19.700	4.271	5.727	22.93	12.00	20.13	19.17
N4	13.670	3.244	4.367	24.03	11.83	19.30	20.77
N5	15.230	2.986	4.020	22.10	11.83	22.03	18.90
			Depth 0-120 cm				
J0	19.770	3.855	5.717	24.77	8.00	48.40	16.77
J1	14.820	3.282	4.741	27.30	9.00	46.00	18.17
J2	15.270	2.657	4.012	27.15	7.38	46.35	17.62
J3	11.420	3.499	5.102	25.70	8.63	36.85	19.37
J4	12.670	2.511	3.698	28.13	8.25	49.90	16.82
K1	14.920	3.274	4.619	28.93	10.00	21.45	19.90
K2	14.770	2.953	4.573	26.70	6.38	22.63	22.45
K3	8.750	2.065	3.142	22.75	7.13	44.75	19.30
K4	14.170	2.595	4.008	29.00	6.50	48.02	18.92
K5	18.120	3.157	4.603	24.97	8.63	39.27	18.60
L1	12.370	2.986	4.287	26.13	9.25	22.95	22.07
L2	13.920	2.757	4.246	25.40	6.63	22.88	24.05
L4	10.720	2.347	3.635	26.57	6.38	22.37	20.92
L5	17.070	3.348	4.899	27.60	8.50	31.72	18.97
M1	14.900	3.135	4.529	24.10	9.00	21.07	20.30
M2	10.750	2.156	3.134	23.20	8.75	27.80	20.45
M3	16.250	3.694	5.075	23.57	11.00	23.75	21.60
M4	11.500	2.516	3.669	23.93	8.63	22.77	21.70
M5	11.570	2.521	3.630	24.77	9.13	17.80	23.65
N1	12.950	3.565	5.029	24.20	10.00	17.97	23.52
N2	13.650	3.391	4.853	25.00	9.38	25.13	21.85
N3	18.020	3.832	5.298	22.80	10.75	20.35	19.80
N4	12.670	3.041	4.232	23.65	10.50	23.07	19.85
N5	14.370	2.980	4.175	22.37	10.25	21.77	18.77

NOBLEFORD SALINITY SURVEY #2, AUG 21-24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm				
J0	38.800	5.250	5.958	26.80	19.00	29.70	19.60
J1	28.300	4.142	4.700	25.20	19.00	27.60	19.30
J2	31.100	4.610	5.231	27.70	19.00	26.90	19.30
J3	30.300	4.864	5.409	26.10	20.00	24.10	21.90
J4	32.700	4.610	5.126	27.20	20.00	32.40	20.00
J5	34.500	3.842	4.174	23.60	21.00	33.70	19.00
K1	31.900	5.302	5.896	21.80	20.00	29.40	18.00
K2	22.600	4.142	4.606	23.20	20.00	30.30	20.40
K3	27.600	4.047	4.397	13.00	21.00	42.10	20.90
K4	29.600	5.250	5.462	24.40	23.00	34.40	20.50
K5	37.700	5.410	5.749	25.90	22.00	26.00	19.90
L1	17.800	0.962	0.981	14.20	24.00	30.00	19.10
L2	23.700	4.142	4.606	25.50	20.00	32.10	23.00
L4	19.100	3.253	3.691	19.80	19.00	35.40	18.10
L5	26.700	3.399	3.466	22.40	24.00	30.10	22.20
M1	7.800	0.421	0.421	10.60	25.00	32.00	22.20
M2	11.100	0.198	0.202	9.30	24.00	33.60	19.80
M3	29.400	1.477	1.537	15.40	23.00	26.50	20.50
M4	15.600	2.897	3.287	25.80	19.00	29.70	19.60
M5	24.100	2.691	2.860	19.60	22.00	26.50	20.20
N1	13.200	0.424	0.451	14.00	22.00	17.20	19.99
N2	11.500	0.624	0.663	13.40	22.00	25.60	18.80
N3	20.700	0.723	0.804	12.20	20.00	26.80	19.10
N4	21.600	1.756	1.866	16.40	22.00	25.80	18.70
N5	13.100	0.553	0.588	12.30	22.00	29.30	18.00
			Depth 0-60cm				
J0	26.700	3.685	4.182	23.95	19.00	38.95	18.80
J1	19.550	3.445	3.951	25.30	18.50	35.35	19.10
J2	20.350	3.737	4.333	27.15	18.00	36.00	17.70
J3	20.350	3.685	4.182	26.25	19.00	24.10	21.60
J4	21.250	3.235	3.671	26.10	19.00	40.45	18.35
J5	27.600	2.653	2.950	20.05	20.00	33.95	17.15
K1	26.750	3.685	4.139	26.50	19.50	24.60	19.50
K2	17.850	3.445	3.909	24.45	19.00	26.55	21.80
K3	20.000	3.316	3.724	20.10	19.50	38.45	19.90
K4	19.100	3.585	3.852	25.45	21.50	37.80	20.60
K5	31.300	3.790	4.118	24.95	21.00	28.35	20.15
L1	16.650	2.036	2.212	17.00	21.00	26.80	20.15
L2	19.600	3.537	4.014	24.85	19.00	28.15	23.30
L4	14.500	2.822	3.237	23.20	18.50	26.90	19.80
L5	20.650	3.121	3.317	25.50	22.00	23.25	20.00
M1	12.800	1.354	1.394	11.80	23.50	23.60	21.15
M2	13.300	0.456	0.490	9.90	21.50	33.65	20.45
M3	30.850	2.948	3.203	19.55	21.00	20.95	22.90
M4	15.600	2.915	3.380	26.05	18.00	22.60	22.00
M5	17.950	2.073	2.328	22.45	19.50	19.45	23.85
N1	16.400	2.248	2.471	16.75	20.50	15.45	22.00
N2	14.050	1.608	1.788	15.40	20.00	20.30	21.10
N3	21.650	1.507	1.710	13.25	19.00	21.00	18.90
N4	18.100	1.951	2.120	16.05	21.00	19.90	21.20
N5	12.100	2.248	2.471	16.05	20.50	25.20	17.40

NOBLEFORD SALINITY SURVEY #2, AUG 21-24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-90 cm				
J0	21.730	2.947	3.392	22.33	18.33	44.30	17.40
J1	15.930	2.898	3.385	24.97	17.67	40.47	19.27
J2	16.170	2.947	3.469	26.67	17.33	41.70	17.17
J3	17.030	3.157	3.634	25.67	18.33	30.13	20.13
J4	16.800	2.679	3.084	24.97	18.33	45.27	17.50
J5	21.600	2.210	2.508	18.70	19.00	39.37	16.20
K1	23.000	3.336	3.786	26.67	19.00	22.20	20.03
K2	14.670	3.048	3.509	24.47	18.33	22.63	22.33
K3	16.400	3.048	3.483	20.47	18.67	40.33	19.30
K4	14.900	2.898	3.198	25.17	20.33	43.93	19.30
K5	23.670	3.048	3.363	22.43	20.33	34.10	19.00
L1	13.970	3.048	3.435	18.80	19.33	24.50	21.93
L2	17.000	3.215	3.728	24.67	18.00	24.37	24.33
L4	12.530	2.562	2.993	23.57	17.67	23.87	21.53
L5	16.630	2.762	3.024	24.40	20.67	25.13	19.47
M1	13.700	2.183	2.354	14.40	21.33	21.43	21.13
M2	14.030	1.637	1.832	11.57	19.67	31.50	19.47
M3	26.470	3.157	3.511	20.50	20.00	19.57	22.93
M4	13.670	2.679	3.178	24.80	17.00	21.90	21.33
M5	13.900	1.823	2.114	22.17	18.00	18.33	23.93
N1	15.330	3.274	3.715	17.87	19.00	15.87	21.85
N2	14.000	2.456	2.807	16.80	18.67	22.83	21.90
N3	19.600	2.267	2.629	14.57	18.00	20.13	19.17
N4	15.370	2.056	2.286	16.97	20.00	19.30	20.77
N5	12.330	2.130	2.384	17.63	19.67	22.03	18.90
			Depth 0-120 cm				
J0	18.770	2.550	2.973	21.57	17.75	48.40	16.77
J1	13.720	2.652	3.146	24.80	17.00	46.00	18.17
J2	14.200	2.706	3.248	26.15	16.50	46.35	17.62
J3	14.870	2.821	3.289	25.13	17.75	36.85	19.37
J4	14.320	2.368	2.761	24.38	17.75	49.90	16.82
J5	18.550	1.950	2.249	18.15	18.25	44.65	16.12
K1	19.850	3.014	3.476	26.05	18.25	21.45	19.90
K2	12.850	2.762	3.220	24.47	17.75	22.63	22.45
K3	14.070	2.821	3.289	20.70	17.75	44.75	19.30
K4	13.050	2.550	2.864	26.10	19.50	48.02	18.92
K5	19.970	2.600	2.920	22.10	19.50	39.27	18.60
L1	12.550	2.502	2.885	19.77	18.25	22.95	22.07
L2	14.970	3.014	3.555	24.22	17.25	22.88	24.05
L4	11.250	2.326	2.759	23.50	17.00	22.37	20.92
L5	14.550	2.550	2.864	24.05	19.50	31.72	18.97
M1	12.620	2.174	2.417	16.35	20.00	21.07	20.30
M2	13.970	1.745	2.001	13.95	18.50	27.80	20.45
M3	21.600	2.762	3.134	20.57	19.00	23.75	21.60
M4	12.500	2.411	2.912	24.30	16.25	22.77	21.70
M5	11.870	1.768	2.097	22.10	17.00	17.80	23.65
N1	13.570	2.883	3.343	18.05	18.00	17.97	23.52
N2	13.250	1.979	2.321	17.22	17.50	25.13	21.85
N3	17.170	2.139	2.537	16.38	17.00	20.35	19.80
N4	13.070	1.922	2.181	18.17	19.00	23.07	19.85
N5	11.320	1.868	2.120	18.40	19.00	21.77	18.77

NOBLEFORD SALINITY SURVEY #3, SEPT 29-30, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm				
J0	36.400	4.311	5.375	24.50	15.00	29.70	19.60
J1	28.700	3.511	4.478	24.80	14.00	27.60	19.30
J2	26.600	4.242	5.289	24.30	15.00	26.90	19.30
J3	27.600	3.870	4.703	24.20	16.00	24.10	21.90
J4	26.700	3.511	4.267	25.90	16.00	32.40	20.00
J5	28.000	3.607	4.383	21.60	16.00	33.70	19.00
K1	30.500	3.682	4.178	21.20	19.00	29.40	18.00
K2	22.400	3.065	3.636	21.90	17.00	30.30	20.40
K3	24.300	2.466	2.925	19.30	17.00	42.10	20.90
K4	29.100	3.870	4.591	23.70	17.00	34.40	20.50
K5	36.000	4.276	5.072	19.70	17.00	26.00	19.90
L1	17.600	1.727	2.002	12.00	18.00	30.00	19.10
L2	23.700	3.465	3.932	21.40	19.00	32.10	23.00
L4	20.300	2.346	2.662	20.20	19.00	35.40	18.10
L5	25.400	3.030	3.438	17.40	19.00	30.10	22.20
M1	7.900	0.152	0.172	25.00	19.00	32.00	22.20
M2	6.700	0.216	0.240	5.20	20.00	33.60	19.80
M3	25.500	3.194	3.625	12.30	19.00	26.50	20.50
M4	16.400	2.378	2.699	19.60	19.00	29.70	19.60
M5	17.200	1.733	1.927	18.00	20.00	26.50	20.20
N1	11.000	2.612	2.964	7.30	19.00	17.20	19.99
N2	11.400	1.773	1.972	14.00	20.00	25.60	18.80
N3	25.800	1.250	1.390	10.90	20.00	26.80	19.10
N4	16.700	1.616	1.834	10.50	19.00	25.80	18.70
N5	18.200	1.578	1.755	13.30	20.00	29.30	18.00
			Depth 0-60cm				
J0	26.700	3.235	3.931	22.30	16.00	38.95	18.80
J1	21.600	2.948	3.760	25.20	14.00	35.35	19.10
J2	22.000	3.316	4.135	25.20	15.00	36.00	17.70
J3	20.300	2.915	3.542	24.90	16.00	24.10	21.60
J4	17.800	2.653	3.224	24.80	16.00	40.45	18.35
J5	25.000	2.653	3.224	19.60	16.00	33.95	17.15
K1	22.800	3.445	3.995	25.70	18.00	24.60	19.50
K2	17.000	2.627	3.192	24.30	16.00	26.55	21.80
K3	20.200	2.503	3.042	23.40	16.00	38.45	19.90
K4	21.000	3.015	3.664	23.90	16.00	37.80	20.60
K5	27.800	3.275	3.980	21.30	16.00	28.35	20.15
L1	20.600	2.193	2.665	17.30	16.00	26.80	20.15
L2	21.300	3.085	3.577	22.30	18.00	28.15	23.30
L4	18.600	2.479	2.874	23.80	18.00	26.90	19.80
L5	20.200	3.049	3.617	21.60	17.00	23.25	20.00
M1	13.300	1.922	2.280	18.80	17.00	23.60	21.15
M2	11.300	1.326	1.538	7.10	18.00	33.65	20.45
M3	28.800	4.279	4.962	12.30	18.00	20.95	22.90
M4	15.800	2.479	2.941	21.20	17.00	22.60	22.00
M5	16.600	2.307	2.675	20.90	18.00	19.45	23.85
N1	17.500	4.211	4.995	12.30	17.00	15.45	22.00
N2	15.800	3.015	3.496	17.30	18.00	20.30	21.10
N3	28.900	2.503	2.902	12.90	18.00	21.00	18.90
N4	15.100	1.855	2.151	12.60	18.00	19.90	21.20
N5	16.200	1.842	2.136	16.10	18.00	25.20	17.40

NOBLEFORD SALINITY SURVEY #3, SEPT 29-30, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-90 cm				
J0	21.400	4.082	5.090	20.70	15.00	44.30	17.40
J1	17.900	3.790	4.833	25.10	14.00	40.47	19.27
J2	18.000	4.349	5.423	24.90	15.00	41.70	17.17
J3	17.400	4.082	5.090	24.70	15.00	30.13	20.13
J4	15.000	3.358	4.081	24.10	16.00	45.27	17.50
J5	20.100	3.358	4.187	17.10	15.00	39.37	16.20
K1	19.200	4.145	4.806	25.70	18.00	22.20	20.03
K2	13.800	3.685	4.478	23.80	16.00	22.63	22.33
K3	16.500	3.445	4.186	99.90	16.00	40.33	19.30
K4	16.800	3.960	4.812	23.50	16.00	43.93	19.30
K5	21.500	3.737	4.541	21.00	16.00	34.10	19.00
L1	17.800	3.491	4.242	18.90	16.00	24.50	21.93
L2	18.300	4.082	4.842	22.50	17.00	24.37	24.33
L4	16.000	3.585	4.253	23.60	17.00	23.87	21.53
L5	16.700	3.537	4.298	21.40	16.00	25.13	19.47
M1	15.200	3.158	3.838	18.60	16.00	21.43	21.13
M2	13.100	2.390	2.835	10.30	17.00	31.50	19.47
M3	25.400	4.737	5.619	14.90	17.00	19.57	22.93
M4	13.800	3.445	4.186	20.60	16.00	21.90	21.33
M5	14.000	2.680	3.179	20.50	17.00	18.33	23.93
N1	17.700	5.414	6.579	14.70	16.00	15.87	21.85
N2	15.500	3.685	4.371	17.90	17.00	22.83	21.90
N3	27.500	3.401	4.034	14.20	17.00	20.13	19.17
N4	13.900	2.915	3.542	13.90	16.00	19.30	20.77
N5	15.100	3.049	3.802	17.10	15.00	22.03	18.90
			Depth 0-120 cm				
J0	19.200	4.913	6.266	23.50	14.00	48.40	16.77
J1	15.700	4.737	6.041	24.40	14.00	46.00	18.17
J2	16.300	5.306	6.616	24.70	15.00	46.35	17.62
J3	16.200	5.006	6.083	24.50	16.00	36.85	19.37
J4	13.900	4.082	5.090	23.80	15.00	49.90	16.82
J5	16.700	5.006	5.805	16.60	18.00	44.65	16.12
K1	16.900	4.913	5.970	25.24	16.00	21.45	19.90
K2	12.300	4.913	5.970	24.10	16.00	22.63	22.45
K3	14.600	4.497	5.465	21.70	16.00	44.75	19.30
K4	14.800	4.824	5.862	23.20	16.00	48.02	18.92
K5	19.000	4.422	5.374	20.60	16.00	39.27	18.60
L1	15.500	4.913	5.970	19.80	16.00	22.95	22.07
L2	15.700	5.006	6.083	22.10	16.00	22.88	24.05
L4	15.000	4.574	5.558	23.40	16.00	22.37	20.92
L5	14.900	4.574	5.558	20.90	16.00	31.72	18.97
M1	14.400	4.211	5.117	19.40	16.00	21.07	20.30
M2	12.900	3.685	4.478	12.50	16.00	27.80	20.45
M3	21.900	5.414	6.579	16.30	16.00	23.75	21.60
M4	12.000	4.497	5.607	20.20	15.00	22.77	21.70
M5	11.900	3.585	4.357	20.60	16.00	17.80	23.65
N1	16.000	6.030	7.328	15.50	16.00	17.97	23.52
N2	14.700	4.824	5.862	18.20	16.00	25.13	21.85
N3	24.200	4.574	5.558	18.20	16.00	20.35	19.80
N4	12.300	3.491	4.242	15.00	16.00	23.07	19.85
N5	14.000	4.654	5.656	17.70	16.00	21.77	18.77

NOBLEFORD SALINITY SURVEY #4, APR 25-26, 1980 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm				
J0	28.200	4.932	6.365	25.00	13.50	29.70	19.60
J1	19.000	4.713	5.800	21.40	15.50	27.60	19.30
J2	21.000	3.607	4.712	30.30	13.00	26.90	19.30
J3	20.800	5.865	7.313	23.80	15.00	24.10	21.90
J4	21.800	4.551	5.531	24.70	16.00	32.40	20.00
J5	26.700	4.474	5.506	23.40	15.50	33.70	19.00
K1	19.000	4.909	5.823	19.30	17.00	29.40	18.00
K2	28.300	4.501	5.339	21.90	17.00	30.30	20.40
K3	13.300	4.524	5.305	15.30	17.50	42.10	20.90
K4	28.400	3.607	4.279	23.10	17.00	34.40	20.50
K5	29.700	6.895	8.085	24.60	17.50	26.00	19.90
L1	14.100	3.558	4.271	20.10	16.50	30.00	19.10
L2	15.700	3.870	4.646	21.50	16.50	32.10	23.00
L3	11.600	1.597	1.776	12.60	20.00	33.90	21.20
L4	28.700	3.388	4.117	20.40	16.00	35.40	18.10
L5	20.700	5.239	6.215	19.60	17.00	30.10	22.20
M1	6.000	2.030	2.257	20.70	20.00	32.00	22.20
M2	6.100	2.169	2.461	16.60	19.00	33.60	19.80
M3	16.800	6.737	7.812	17.00	18.00	26.50	20.50
M4	9.800	3.578	4.461	22.40	15.00	29.70	19.60
M5	20.800	4.242	5.155	21.30	16.00	26.50	20.20
N1	7.000	3.033	4.279	19.20	10.00	17.20	19.99
N2	12.600	6.380	8.765	27.10	11.00	25.60	18.80
N3	13.300	2.885	3.869	20.70	12.00	26.80	19.10
N4	13.600	3.957	5.306	19.90	12.00	25.80	18.70
N5	15.300	2.823	3.785	22.80	12.00	29.30	18.00
			Depth 0-60cm				
J0	21.050	4.638	6.293	23.65	11.50	38.95	18.80
J1	14.300	3.477	4.571	21.70	12.75	35.35	19.10
J2	15.150	3.742	5.208	25.95	10.50	36.00	17.70
J3	15.950	4.107	5.507	22.90	12.00	24.10	21.60
J4	15.400	3.397	4.495	22.10	12.50	40.45	18.35
J5	24.650	2.769	3.688	21.75	12.25	33.95	17.15
K1	16.700	3.726	4.808	22.75	13.50	24.60	19.50
K2	23.500	3.362	4.313	24.40	13.75	26.55	21.80
K3 -	18.500	2.881	3.653	19.55	14.25	38.45	19.90
K4	20.650	3.397	4.358	24.70	13.75	37.80	20.60
K5	23.000	4.582	5.878	26.65	13.75	28.35	20.15
L1	16.350	3.936	5.110	22.25	13.25	26.80	20.15
L2	15.750	4.050	5.258	22.90	13.25	28.15	23.30
L3	12.500	1.871	2.260	15.60	16.25	29.70	21.70
L4	21.400	3.074	4.122	24.80	12.00	26.90	19.80
L5	16.150	3.437	4.490	23.55	13.00	23.25	20.00
M1	12.650	3.114	3.694	20.85	17.00	23.60	21.15
M2	9.900	2.281	2.807	19.05	15.50	33.65	20.45
M3	16.950	4.886	6.160	20.90	14.50	20.95	22.90
M4	8.000	2.744	3.679	23.75	12.00	22.60	22.00
M5	16.950	3.384	4.478	22.05	12.50	19.45	23.85
N1	13.650	4.225	6.066	19.50	9.25	15.45	22.00
N2	15.000	4.075	5.749	25.45	10.00	20.30	21.10
N3	16.150	4.646	6.382	22.30	11.00	21.00	18.90
N4	15.300	3.823	5.252	20.90	11.00	19.90	21.20
N5	11.850	2.718	3.783	23.00	10.50	25.20	17.40

NOBLEFORD SALINITY SURVEY #4, APR 25-26, 1980 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-90 cm				
J0	18.100	3.894	5.515	21.77	9.83	44.30	17.40
J1	12.530	3.157	4.356	20.17	10.83	40.47	19.27
J2	13.570	2.917	4.214	24.70	9.00	41.70	17.17
J3	13.970	3.268	4.610	22.53	10.00	30.13	20.13
J4	13.300	2.559	3.593	21.67	10.17	45.27	17.50
J5	19.900	2.671	3.751	19.70	10.17	39.37	16.20
K1	14.970	3.262	4.481	22.87	11.00	22.20	20.03
K2	19.300	3.069	4.164	24.60	11.50	22.63	22.33
K3	15.900	3.007	4.014	19.70	12.17	40.33	19.30
K4	16.970	3.012	4.087	23.43	11.50	43.93	19.30
K5	18.130	3.938	5.343	24.63	11.50	34.10	19.00
L1	14.300	3.529	4.827	23.47	11.17	24.50	21.93
L2	16.400	3.323	4.546	22.93	11.17	24.37	24.33
L3	11.670	2.462	3.152	16.53	13.83	30.60	21.07
L4	18.730	2.884	4.116	24.30	9.50	23.87	21.53
L5	14.700	3.197	4.429	23.20	10.67	25.13	19.47
M1	13.900	2.861	3.621	20.80	14.33	21.43	21.13
M2	13.370	2.164	2.827	19.87	13.00	31.50	19.47
M3	14.430	3.886	5.165	20.73	12.33	19.57	22.93
M4	9.600	2.852	4.024	22.70	10.00	21.90	21.33
M5	14.470	2.619	3.677	21.63	10.17	18.33	23.93
N1	13.970	3.877	5.723	20.53	8.17	15.87	21.85
N2	14.600	3.676	5.310	24.90	9.00	22.83	21.90
N3	14.170	3.250	4.620	21.90	9.67	20.13	19.17
N4	14.600	3.973	5.648	21.40	9.67	19.30	20.77
N5	13.130	2.619	3.783	23.13	9.00	22.03	18.90
			Depth 0-120 cm				
J0	17.020	3.211	4.682	21.22	8.63	48.40	16.77
J1	10.950	2.876	4.116	20.50	9.38	46.00	18.17
J2	12.720	2.827	4.222	23.80	7.75	46.35	17.62
J3	12.470	2.876	4.194	21.50	8.63	36.85	19.37
J4	11.500	2.181	3.180	21.75	6.63	49.90	16.82
J5	16.850	2.347	3.401	18.62	8.88	44.65	16.12
K1	14.550	2.852	4.082	22.63	9.38	21.45	19.90
K2	16.770	2.590	3.664	24.32	9.88	22.63	22.45
K3	14.000	2.615	3.627	20.22	10.63	44.75	19.30
K4	14.500	2.757	3.890	21.77	10.00	48.02	18.92
K5	15.550	3.048	4.312	23.60	9.88	39.27	18.60
L1	12.120	2.940	4.172	23.00	9.75	22.95	22.07
L2	15.720	2.595	3.692	22.55	9.63	22.88	24.05
L3	12.800	2.960	3.980	18.45	11.88	31.25	20.92
L4	15.920	2.511	3.737	23.57	7.88	22.37	20.92
L5	12.850	2.827	4.084	22.55	9.00	31.72	18.97
M1	13.200	2.335	3.099	21.20	12.38	21.07	20.30
M2	16.370	1.905	2.601	20.07	11.25	27.80	20.45
M3	14.020	2.774	3.835	21.15	10.75	23.75	21.60
M4	9.700	2.570	3.736	22.45	8.75	22.77	21.70
M5	12.350	2.322	3.386	21.88	8.63	17.80	23.65
N1	14.100	3.603	5.441	20.55	7.38	17.97	23.52
N2	13.700	3.055	4.531	24.35	8.00	25.13	21.85
N3	13.120	3.113	4.525	21.52	8.75	20.35	19.80
N4	13.050	3.105	4.543	21.27	8.50	23.07	19.85
N5	12.250	2.745	4.085	23.13	7.88	21.77	18.77

NOBLEFORD SALINITY SURVEY #5, MAY 14-22, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm				
A1	21.600	5.198	6.166	31.90	17.00	25.30	22.10
A2	33.700	7.013	8.631	25.80	15.50	30.30	20.10
A3	22.100	4.110	5.511	23.40	12.00	34.80	17.10
B1	19.200	5.665	6.884	31.40	16.00	28.80	21.30
B2	17.400	4.946	7.145	29.00	9.00	33.00	20.30
B3	20.700	5.040	6.758	27.90	12.00	30.10	22.40
B4	19.700	6.032	8.088	30.50	12.00	30.90	18.00
B5	29.900	6.895	8.486	26.20	15.50	25.30	19.90
C1	13.100	2.599	3.667	46.80	10.00	34.60	18.10
C2	10.200	1.597	2.440	33.40	7.00	29.10	20.20
C3	15.500	4.364	5.921	37.10	11.50	26.20	17.30
C4	14.500	4.798	6.591	33.40	11.00	28.30	14.10
C5	13.200	3.381	4.417	28.80	13.00	25.60	17.00
D1	12.500	3.682	5.058	32.40	11.00	32.70	16.80
D2	16.400	3.273	5.001	58.30	7.00	29.50	16.50
D3	16.000	4.191	5.913	29.80	10.00	25.50	18.10
D4	13.800	2.075	3.036	34.70	8.50	26.50	19.90
D5	15.200	5.534	7.421	31.40	12.00	26.40	23.30
E1	11.100	3.083	4.454	34.10	9.00	30.40	17.60
E2	18.000	2.678	4.092	41.80	7.00	30.20	19.60
E3	14.700	4.437	6.492	30.00	8.50	29.60	20.70
E4	99.999	4.175	5.810	99.99	10.50	27.50	21.80
E5	13.900	3.652	4.771	29.80	13.00	25.60	20.00
			Depth 0-60cm				
A1	18.500	4.321	5.388	32.85	15.00	23.30	19.15
A2	34.050	6.455	8.656	29.30	12.00	21.70	19.70
A3	23.950	4.026	5.603	25.25	10.50	38.10	15.65
B1	19.350	4.342	5.475	33.50	14.50	24.50	19.10
B2	18.800	4.922	7.300	31.35	8.00	27.15	16.80
B3	20.450	4.886	6.800	30.85	10.50	23.70	20.00
B4	18.150	4.558	6.343	29.55	10.50	32.15	18.50
B5	25.200	5.338	7.018	29.50	12.75	24.80	16.60
C1	11.450	2.479	3.581	41.95	9.00	35.75	15.60
C2	11.200	2.563	4.006	35.60	6.00	24.80	18.75
C3	13.700	3.495	4.897	38.90	10.25	19.65	18.65
C4	16.350	4.120	5.880	32.05	9.50	30.60	16.55
C5	13.050	3.983	5.472	30.65	11.00	22.25	18.05
D1	11.450	2.423	3.458	35.85	9.50	36.35	15.80
D2	13.950	2.211	3.577	50.35	4.75	30.45	17.20
D3	15.450	4.165	5.980	32.75	9.25	19.80	19.35
D4	15.550	3.428	5.158	32.85	7.50	23.25	21.00
D5	17.700	5.414	7.586	33.45	10.25	20.65	23.25
E1	10.750	2.890	4.286	34.95	8.00	30.40	20.40
E2	15.750	2.041	3.329	38.65	4.50	34.05	18.50
E3	12.950	3.354	5.010	32.30	7.75	31.70	21.45
E4	12.800	3.890	5.520	32.90	9.75	22.70	22.50
E5	15.450	2.991	4.109	31.55	11.00	22.50	20.85

NOBLEFORD SALINITY SURVEY #5, MAY 14-22, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-90 cm				
A1	16.000	3.387	4.425	30.80	13.00	29.07	17.07
A2	30.200	4.604	6.545	29.37	9.67	23.63	18.27
A3	20.900	3.579	5.128	25.37	9.33	42.60	16.13
B1	19.233	3.699	4.873	33.03	12.67	31.00	17.03
B2	19.400	4.312	6.521	31.80	7.33	23.47	18.17
B3	19.200	4.557	6.530	30.77	9.33	20.03	20.83
B4	18.200	4.037	5.762	25.93	9.50	35.80	18.37
B5	22.500	3.938	5.410	29.47	11.00	21.40	17.63
C1	10.667	2.070	3.070	39.40	8.00	33.40	16.00
C2	10.733	2.425	3.822	36.73	5.67	21.37	19.50
C3	12.900	3.368	4.826	37.47	9.33	21.17	19.00
C4	16.433	3.668	5.367	31.77	8.50	32.67	15.77
C5	12.700	3.336	4.743	30.80	9.67	18.97	18.80
D1	10.567	2.529	3.717	34.53	8.33	32.80	15.67
D2	12.633	1.861	3.124	44.83	3.50	26.50	19.03
D3	15.433	3.586	5.294	32.60	8.17	22.77	19.77
D4	15.933	3.091	4.739	32.17	6.83	26.20	19.93
D5	18.733	4.884	7.026	33.60	9.17	17.60	23.33
E1	9.933	2.562	3.674	35.63	7.33	27.47	20.37
E2	14.633	2.272	3.883	40.17	2.83	30.83	19.17
E3	12.100	3.022	4.633	36.37	6.83	35.33	19.63
E4	12.200	3.226	4.680	31.50	8.83	19.63	23.17
E5	14.133	3.135	4.440	32.60	9.83	18.90	22.37
			Depth 0-120 cm				
A1	14.375	3.007	4.105	30.50	11.25	32.02	16.85
A2	26.100	3.970	5.809	28.27	8.50	26.60	18.17
A3	18.575	3.000	4.320	24.70	9.12	46.67	16.15
B1	18.850	3.048	4.214	32.25	10.75	28.40	20.92
B2	20.125	4.055	6.228	32.50	6.75	20.92	19.70
B3	18.225	3.912	5.724	30.10	8.50	23.92	19.40
B4	17.525	3.565	5.182	25.85	8.75	34.95	16.95
B5	19.700	2.876	4.081	28.45	9.75	24.32	16.82
C1	10.600	1.884	2.856	37.82	7.25	32.85	14.68
C2	10.900	2.550	4.065	37.70	5.25	20.98	19.18
C3	12.450	2.852	4.159	36.38	8.62	19.88	21.22
C4 -	16.550	3.218	4.806	32.00	7.75	35.52	15.78
C5	99.999	2.914	4.236	99.99	8.75	22.12	18.48
D1	10.225	2.267	3.411	34.58	7.50	29.90	16.28
D2	11.675	1.720	2.959	41.30	2.62	22.55	20.68
D3	15.025	3.299	4.964	31.60	7.50	26.12	19.18
D4	15.900	2.768	4.287	31.90	6.38	33.10	19.32
D5	19.275	4.118	6.045	33.72	8.38	17.35	22.38
E1	8.375	2.335	3.586	35.60	6.75	24.22	21.62
E2	13.775	2.003	3.540	39.60	1.88	32.25	18.98
E3	11.400	2.545	3.965	34.65	6.12	35.82	20.05
E4	12.200	2.889	4.270	31.70	8.12	21.08	21.92
E5	13.000	2.953	4.266	32.80	9.00	19.12	22.05

NOBLEFORD SALINITY SURVEY #6, SEPT 25, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm				
A1	32.500	3.356	4.280	22.80	14.00	25.30	22.10
A2	39.500	3.421	4.363	22.00	14.00	30.30	20.10
A3	32.700	2.218	2.766	17.70	15.00	34.80	17.10
B1	33.800	4.311	5.498	25.60	14.00	28.80	21.30
B2	35.000	3.101	3.955	21.70	14.00	33.00	20.30
B3	23.500	2.501	3.190	18.80	14.00	30.10	22.40
B4	23.500	2.356	2.938	19.60	15.00	30.90	18.00
B5	32.300	2.851	3.465	17.20	16.00	25.30	19.90
C1	19.800	3.101	4.051	29.40	13.00	34.60	18.10
C2	15.000	0.942	1.145	21.50	16.00	29.10	20.20
C3	21.700	3.399	4.286	28.10	14.50	26.20	17.30
C4	22.200	0.869	1.069	19.30	15.50	28.30	14.10
C5	26.500	2.147	2.677	22.30	15.00	25.60	17.00
D1	23.000	3.293	4.106	31.50	15.00	32.70	16.80
D2	24.500	3.356	4.231	34.00	14.50	29.50	16.50
D3	21.200	2.962	3.645	21.10	15.50	25.50	18.10
D4	25.800	1.744	2.224	22.30	14.00	26.50	19.90
D5	7.200	0.067	0.081	13.10	16.00	26.40	23.30
E1	21.600	2.835	3.616	27.70	14.00	30.40	17.60
E2	26.800	3.682	4.591	28.10	15.00	30.20	19.60
E3	28.000	3.233	4.172	25.10	13.50	29.60	20.70
E4	23.700	2.443	3.080	21.50	14.50	27.50	21.80
E5	22.800	2.031	2.532	19.10	15.00	25.60	20.00
			Depth 0-60cm				
A1	27.250	2.576	3.285	20.95	14.00	23.30	19.15
A2	33.150	3.015	3.845	24.20	14.00	21.70	19.70
A3	26.800	1.855	2.313	16.85	15.00	38.10	15.65
B1	24.000	3.121	4.028	26.15	13.50	24.50	19.10
B2	30.000	2.884	3.722	23.50	13.50	27.15	16.80
B3	23.350	3.121	4.028	21.90	13.50	23.70	20.00
B4	21.100	1.868	2.355	18.45	14.50	32.15	18.50
B5	25.650	2.412	2.968	18.30	15.50	24.80	16.60
C1	14.600	2.456	3.250	30.30	12.50	35.75	15.60
C2	12.700	1.589	2.003	32.05	14.50	24.80	18.75
C3	17.350	3.158	4.051	30.55	13.75	19.65	18.65
C4	20.950	1.450	1.860	17.85	13.75	30.60	16.55
C5	22.600	2.390	3.048	22.40	14.00	22.25	18.05
D1	16.500	2.479	3.161	31.70	14.00	36.35	15.80
D2	17.000	2.601	3.357	29.05	13.50	30.45	17.20
D3	20.100	2.884	3.636	24.15	14.50	19.80	19.35
D4	22.400	1.734	2.251	21.90	13.25	23.25	21.00
D5	10.100	0.214	0.270	14.85	14.50	20.65	23.25
E1	17.550	2.073	2.692	26.50	13.25	30.40	20.40
E2	19.650	3.049	3.888	25.70	14.00	34.05	18.50
E3	22.500	2.140	2.814	24.75	12.75	31.70	21.45
E4	18.650	2.025	2.629	20.95	13.25	22.70	22.50
E5	20.200	1.561	1.991	18.25	14.00	22.50	20.85

NOBLEFORD SALINITY SURVEY #6, SEPT 25, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-90 cm				
A1	23.167	2.130	2.716	18.47	14.00	29.07	17.07
A2	27.600	2.562	3.267	22.17	14.00	23.63	18.27
A3	21.500	1.551	1.948	15.67	14.67	42.60	16.13
B1	19.167	2.639	3.419	23.50	13.33	31.00	17.03
B2	26.267	3.215	4.200	23.77	13.00	23.47	18.17
B3	20.300	2.762	3.593	23.20	13.17	20.03	20.83
B4	19.633	1.987	2.534	18.63	14.00	35.80	18.37
B5	21.633	2.032	2.534	19.00	15.00	21.40	17.63
C1	12.600	2.056	2.745	30.13	12.17	33.40	16.00
C2	11.567	2.210	2.829	30.47	13.83	21.37	19.50
C3	14.200	2.562	3.333	28.70	13.17	21.17	19.00
C4	18.967	1.171	1.523	16.87	13.17	32.67	15.77
C5	19.067	1.901	2.463	21.97	13.33	18.97	18.80
D1	15.267	2.130	2.760	32.07	13.33	32.80	15.67
D2	13.600	2.267	2.962	26.57	13.00	26.50	19.03
D3	17.600	2.105	2.685	22.87	14.00	22.77	19.77
D4	19.233	1.842	2.417	20.43	12.83	26.20	19.93
D5	11.500	0.565	0.723	16.37	13.83	17.60	23.33
E1	15.467	2.032	2.666	28.43	12.83	27.47	20.37
E2	16.267	2.639	3.392	24.90	13.67	30.83	19.17
E3	19.667	2.056	2.732	24.43	12.33	35.33	19.63
E4	16.300	1.842	2.427	20.23	12.67	19.63	23.17
E5	18.367	1.622	2.102	17.97	13.33	18.90	22.37
			Depth 0-120 cm				
A1	19.200	1.792	2.285	16.85	14.00	32.02	16.85
A2	23.050	2.286	2.915	20.70	14.00	26.60	18.18
A3	18.025	1.426	1.798	14.58	14.50	46.68	16.15
B1	15.850	2.286	2.968	22.85	13.25	28.40	20.92
B2	22.300	3.014	3.975	23.30	12.62	20.92	19.70
B3	17.350	2.550	3.342	23.25	12.88	23.92	19.40
B4	18.425	1.979	2.539	18.38	13.75	34.95	16.95
B5	18.225	1.579	1.980	17.72	14.75	24.32	16.82
C1	11.425	1.816	2.442	28.50	11.88	32.85	14.68
C2	10.750	1.816	2.351	28.62	13.38	20.98	19.18
C3	12.075	2.411	3.160	27.00	12.88	19.88	21.22
C4	16.725	1.441	1.895	16.48	12.75	35.52	15.78
C5	17.050	1.816	2.372	20.48	13.00	22.12	18.48
D1	13.650	1.868	2.448	31.22	12.88	29.90	16.28
D2	11.700	2.040	2.691	24.88	12.62	22.55	20.68
D3	15.625	1.816	2.337	21.78	13.62	26.12	19.18
D4	16.650	1.816	2.403	19.52	12.50	33.10	19.32
D5	10.675	1.005	1.301	17.42	13.38	17.35	22.38
E1	14.125	1.842	2.437	28.92	12.50	24.22	21.62
E2	14.250	2.411	3.121	23.78	13.38	32.25	18.98
E3	17.775	1.792	2.403	24.18	12.00	35.82	20.05
E4	14.575	1.894	2.523	20.18	12.25	21.08	21.92
E5	16.025	1.579	2.069	18.05	12.88	19.12	22.05

NOBLEFORD SALINITY SURVEY #7, APR 25-26, 1980 - HEDGEFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-30cm				
V1	11.900	2.913	3.759	24.50	13.50	31.10	26.40
V3	19.700	4.382	5.588	25.50	14.00	26.60	28.50
V5	0.830	0.466	0.581	16.80	15.00	38.00	22.20
V7	0.900	0.223	0.274	12.80	15.50	41.00	23.30
V10	0.620	0.179	0.215	16.20	16.50	34.50	25.40
X1	14.380	4.734	6.264	23.10	12.50	33.60	25.40
X3	18.400	4.978	6.207	25.30	15.00	31.70	31.60
X5	2.000	0.315	0.378	15.30	16.50	41.70	20.20
X7	0.710	0.220	0.261	17.30	17.00	36.30	24.30
X10	0.740	0.228	0.270	10.80	17.00	51.70	16.40
Z1	27.700	8.284	10.565	26.90	14.00	33.80	32.00
Z3	18.300	3.377	4.469	23.80	12.50	32.00	28.00
Z5	0.940	0.320	0.394	23.20	15.50	31.70	25.70
Z7	0.560	0.200	0.237	16.70	17.00	33.80	25.70
Z10	0.550	0.218	0.259	18.10	17.00	29.70	26.80
Z11	0.850	0.291	0.345	18.00	17.00	29.70	37.10
			Depth 0-60cm				
V1	15.650	4.238	5.786	25.15	11.25	28.15	27.90
V3	23.450	3.495	4.686	22.45	12.00	28.80	30.50
V5	1.020	0.494	0.649	14.80	12.75	34.00	23.75
V7	0.860	0.188	0.244	12.70	13.25	42.70	22.75
V10	0.525	0.136	0.172	11.60	14.25	40.30	23.25
X1	17.190	4.996	6.907	25.70	10.75	28.70	29.45
X3	21.100	5.645	7.470	25.45	12.50	30.30	29.45
X5	2.190	0.382	0.484	15.90	14.25	41.85	20.15
X7	0.725	0.199	0.251	15.05	14.50	43.10	20.65
X10	0.720	0.246	0.312	10.65	14.25	45.60	18.95
Z1	30.350	5.327	7.143	22.90	12.00	38.10	30.35
Z3	14.800	2.475	3.468	21.40	10.25	37.20	27.35
Z5	1.845	0.329	0.430	16.40	13.00	41.15	22.05
Z7	0.590	0.170	0.219	16.15	13.50	30.85	28.25
Z10	0.585	0.197	0.248	16.10	14.50	26.20	27.75
Z11	0.780	0.371	0.465	15.55	14.75	26.75	39.10

NOBLEFORD SALINITY SURVEY #7, APR 25-26, 1980 - HEDGEFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECA	ECAT	H2O	TEMP	SAND	CLAY
			Depth 0-90 cm				
V1	15.667	3.754	5.358	24.07	9.50	31.33	25.97
V3	21.767	2.917	4.060	22.73	10.50	30.60	32.50
V5	3.157	0.494	0.676	12.63	11.17	34.07	22.87
V7	0.827	0.170	0.228	10.93	12.00	44.00	20.47
V10	0.543	0.133	0.175	9.33	12.83	43.63	21.83
X1	16.960	4.355	6.265	25.50	9.17	27.80	29.40
X3	14.640	3.738	5.179	24.30	10.67	28.87	32.50
X5	2.630	0.464	0.617	14.87	12.33	42.63	18.73
X7	0.830	0.182	0.238	13.37	13.00	43.67	19.53
X10	0.717	0.180	0.237	9.27	12.67	46.37	18.77
Z1	29.333	5.125	7.165	23.13	10.33	35.43	33.57
Z3	13.330	2.399	3.510	19.83	8.50	35.87	30.53
Z5	3.023	0.347	0.473	14.60	11.33	42.27	20.83
Z7	0.567	0.140	0.189	12.73	11.67	36.80	24.97
Z10	0.597	0.177	0.233	12.57	12.67	30.60	24.63
Z11	0.763	0.359	0.467	14.97	13.17	25.13	39.07
			Depth 0-120cm				
V1	15.500	3.453	5.068	23.32	8.38	36.80	24.23
V3	18.770	2.580	3.693	20.23	9.38	32.52	30.68
V5	3.457	0.534	0.753	11.77	10.00	36.68	20.88
V7	0.777	0.171	0.236	9.80	10.75	44.05	18.55
V10	0.540	0.143	0.195	8.75	11.38	43.23	20.70
X1	16.470	3.633	5.369	24.90	8.13	29.93	28.10
X3	16.355	3.565	5.102	22.98	9.38	26.85	34.55
X5	2.552	0.513	0.705	13.68	11.00	44.05	17.77
X7	0.862	0.202	0.271	12.25	12.00	44.73	18.98
X10	0.717	0.162	0.221	8.68	11.25	45.27	18.40
Z1	28.175	3.889	5.618	26.00	9.00	31.77	36.48
Z1	12.102	2.024	3.056	22.25	7.38	32.38	34.98
Z5	3.317	0.336	0.472	13.27	10.13	43.60	20.23
Z7	0.610	0.133	0.186	11.00	10.25	42.60	22.80
Z10	0.710	0.179	0.244	11.63	11.25	33.57	22.80
Z11	0.705	0.430	0.580	20.50	11.75	26.90	36.20

NOBLEFORD SALINITY SURVEY #1, MAY 24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm			
J0	23.700	5.455	26.20	12.50	29.70	19.60
J1	24.900	4.539	27.50	13.50	27.60	19.30
J2	22.700	3.739	28.70	12.00	26.90	19.30
J3	18.900	5.569	27.40	13.00	24.10	21.90
J4	19.300	4.955	29.00	14.00	32.40	20.00
K1	13.200	4.829	26.00	16.00	29.40	18.00
K2	23.700	4.175	23.50	14.00	30.30	20.40
K3	8.700	2.177	16.30	16.00	42.10	20.90
K4	23.200	4.418	26.80	15.00	34.40	20.50
K5	23.700	6.059	21.90	16.00	26.00	19.90
L1	7.000	1.932	24.00	13.00	30.00	19.10
L2	18.400	3.669	24.00	12.50	32.10	23.00
L4	16.500	3.356	24.00	13.50	35.40	18.10
L5	19.900	3.607	28.60	13.00	30.10	22.20
M1	10.800	1.972	24.50	14.00	32.00	22.20
M2	5.100	1.907	23.40	14.00	33.60	19.80
M3	14.200	3.523	21.80	15.50	26.50	20.50
M4	14.500	2.171	24.00	13.00	29.70	19.60
M5	16.600	3.972	25.50	13.50	26.50	20.20
N1	6.200	1.778	21.00	15.00	17.20	19.90
N2	3.400	2.134	23.10	15.00	25.60	18.80
N3	18.900	4.610	22.50	16.00	26.80	19.10
N4	12.900	1.364	21.30	16.50	25.80	18.70
N5	12.400	3.152	19.20	16.50	29.30	18.00
			Depth 30-60 cm			
J0	13.200	3.507	24.60	9.00	48.20	18.00
J1	12.400	3.675	28.20	10.00	43.10	18.90
J2	16.800	2.525	28.30	8.00	45.10	16.10
J3	10.800	3.245	27.20	9.50	24.10	21.30
J4	14.000	2.657	28.80	9.00	48.50	16.70
K1	21.600	3.941	33.00	11.50	19.80	21.00
K2	14.600	3.395	29.60	8.00	22.80	23.20
K3	12.600	1.905	23.40	8.00	34.80	18.90
K4	13.600	2.782	29.90	7.50	41.20	20.70
K5	24.900	2.843	27.00	9.00	30.70	20.40
L1	13.600	4.818	29.50	10.00	23.60	21.20
L2	16.600	3.239	27.40	8.50	24.20	23.60
L4	11.600	2.600	27.20	8.50	18.40	21.50
L5	21.600	6.005	29.70	9.50	16.40	17.80
M1	14.000	3.684	27.10	9.50	15.20	20.10
M2	9.900	1.933	24.20	9.00	33.70	21170
M3	22.700	4.967	27.00	12.00	15.40	25.30
M4	11.600	2.185	25.30	9.00	15.50	24.40
M5	14.600	2.398	27.20	9.50	12.40	27.50
N1	8.800	3.036	28.00	11.00	13.70	24.00
N2	16.600	3.910	28.30	10.00	15.00	23.40
N3	22.700	4.554	25.30	11.50	15.20	18.70
N4	14.500	3.916	27.50	11.00	14.00	23.70
N5	17.800	2.296	23.40	11.00	21.10	16.80

NOBLEFORD SALINITY SURVEY #1, MAY 24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 60-90 cm			
J0	20.600	3.758	25.00	6.00	55.00	14.60
J1	12.400	2.589	27.50	7.00	50.70	19.60
J2	10.800	2.304	26.60	5.50	53.10	16.10
J3	8.700	3.906	25.20	7.00	42.20	17.20
J4	10.300	1.580	29.50	6.00	54.90	15.80
K1	11.300	2.327	28.60	7.50	17.40	21.10
K2	11.600	2.144	27.40	3.50	14.80	23.40
K3	7.600	2.788	25.70	4.00	44.10	18.10
K4	11.000	1.524	28.90	3.50	56.20	16.70
K5	11.800	2.057	26.00	6.00	45.60	16.70
L1	16.400	2.739	26.40	8.00	19.90	25.50
L2	9.900	2.446	24.70	4.00	16.80	26.40
L4	8.000	2.228	30.10	4.00	17.80	25.00
L5	15.500	2.838	26.40	6.50	28.90	18.40
M1	15.800	3.506	22.50	7.50	17.10	21.10
M2	13.400	2.319	24.70	7.00	27.20	17.50
M3	16.200	4.353	24.20	9.00	16.80	23.00
M4	11.000	3.156	22.30	7.50	20.50	20.00
M5	9.600	2.471	23.10	7.50	16.10	24.10
N1	17.000	4.027	25.00	8.00	16.70	21.60
N2	19.100	3.601	24.70	7.00	27.90	23.50
N3	17.500	3.649	21.00	8.50	18.40	19.70
N4	13.600	4.452	23.30	8.00	18.10	19.90
N5	15.500	3.510	23.70	8.00	15.70	21.90
			Depth 90-120 cm			
J0	21.600	2.700	23.30	4.50	60.70	14.90
J1	9.600	2.325	26.00	5.50	62.60	14.90
J2	10.800	2.060	25.00	4.00	60.30	19.00
J3	7.300	1.276	23.00	5.00	57.00	17.10
J4	7.100	0.852	25.20	4.00	63.80	14.80
K1	13.600	1.999	28.10	5.00	19.20	19.50
K2	9.200	2.098	26.30	0.0	22.60	22.80
K3	6.100	1.390	25.60	0.50	58.00	19.30
K4	8.900	1.656	30.40	0.0	60.30	17.80
K5	12.100	1.669	25.00	3.50	54.80	17.40
L1	12.500	2.455	24.60	6.00	18.30	22.50
L2	10.800	1.674	25.50	1.50	18.40	23.20
L4	6.800	1.204	25.00	-0.50	17.90	19.10
L5	11.300	0.942	25.70	5.00	51.50	17.50
M1	19.000	3.378	22.30	5.00	20.00	17.80
M2	14.600	2.465	20.50	5.00	16.70	23.40
M3	11.900	1.933	21.30	7.50	36.30	17.60
M4	8.900	2.552	24.10	5.00	25.40	22.80
M5	5.500	1.243	23.30	6.00	16.20	22.80
N1	19.800	5.419	22.80	6.00	24.30	28.60
N2	15.500	3.919	23.90	5.50	32.00	21.70
N3	13.000	2.515	22.40	7.00	21.00	21.70
N4	9.700	2.432	22.50	6.50	34.40	17.10
N5	11.800	2.962	23.20	5.50	21.00	18.40

NOBLEFORD SALINITY SURVEY #2, AUG 21-24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm			
J0	38.800	5.250	26.80	19.00	29.70	19.60
J1	28.300	4.142	25.20	19.00	27.60	19.30
J2	31.100	4.610	27.70	19.00	26.90	19.30
J3	30.300	4.864	26.10	20.00	24.10	21.90
J4	32.700	4.610	27.20	20.00	32.40	20.00
J5	34.500	3.842	23.60	21.00	33.70	19.00
K1	31.900	5.302	21.80	20.00	29.40	18.00
K2	22.600	4.142	23.20	20.00	30.30	20.40
K3	27.600	4.047	13.00	21.00	42.10	20.90
K4	29.600	5.250	24.40	23.00	34.40	20.50
K5	37.700	5.410	25.90	22.00	26.00	19.90
L1	17.800	0.962	14.20	24.00	30.00	19.10
L2	23.700	4.142	25.50	20.00	32.10	23.00
L4	19.100	3.253	19.80	19.00	35.40	18.10
L5	26.700	3.399	22.40	24.00	30.10	22.20
M1	7.800	0.421	10.60	25.00	32.00	22.20
M2	11.100	0.198	9.30	24.00	33.60	19.80
M3	29.400	1.477	15.40	23.00	26.50	20.50
M4	15.600	2.897	25.80	19.00	29.70	19.60
M5	24.100	2.691	19.60	22.00	26.50	20.20
N1	13.200	0.424	14.00	22.00	17.20	19.90
N2	11.500	0.624	13.40	22.00	25.60	18.80
N3	20.700	0.723	12.20	20.00	26.80	19.10
N4	21.600	1.756	16.40	22.00	25.80	18.70
N5	13.100	0.553	12.30	22.00	29.30	18.00
			Depth 30-60 cm			
J0	14.600	2.120	21.10	19.00	48.20	18.00
J1	10.800	2.748	25.40	18.00	43.10	18.90
J2	9.600	2.864	26.60	17.00	45.10	16.10
J3	10.400	2.506	26.40	18.00	24.10	21.30
J4	9.800	1.860	25.00	18.00	48.50	16.70
J5	20.700	1.464	16.50	19.00	34.20	15.30
K1	21.600	2.068	31.20	19.00	19.80	21.00
K2	13.100	2.748	25.70	18.00	22.80	23.20
K3	12.400	2.585	27.20	18.00	34.80	18.90
K4	8.600	1.920	26.50	20.00	41.20	20.70
K5	24.900	2.170	24.00	20.00	30.70	20.40
L1	15.500	3.110	19.80	18.00	23.60	21.20
L2	15.500	2.932	24.20	18.00	24.20	23.60
L4	9.900	2.391	26.60	18.00	18.40	21.50
L5	14.600	2.843	28.60	20.00	16.40	17.80
M1	17.800	2.287	13.00	22.00	15.20	20.10
M2	15.500	0.714	10.50	19.00	33.70	21.10
M3	32.300	4.419	23.70	19.00	15.40	25.30
M4	15.600	2.933	26.30	17.00	15.50	24.40
M5	11.800	1.455	25.30	17.00	12.40	27.50
N1	19.600	4.072	19.50	19.00	13.70	24.00
N2	16.600	2.592	17.40	18.00	15.00	23.40
N3	22.600	2.291	14.30	18.00	15.20	18.70
N4	14.600	2.146	15.70	20.00	14.00	23.70
N5	11.100	3.943	19.80	19.00	21.10	16.80

NOBLEFORD SALINITY SURVEY #2, AUG 21-24, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 60-90 cm			
J0	11.800	1.471	19.10	17.00	55.00	14.60
J1	8.700	1.804	24.30	16.00	50.70	19.60
J2	7.800	1.367	25.70	16.00	53.10	16.10
J3	10.400	2.101	24.50	17.00	42.20	17.20
J4	7.900	1.567	22.70	17.00	54.90	15.80
J5	9.600	1.324	16.00	17.00	50.20	14.30
K1	15.500	2.638	27.00	18.00	17.40	21.10
K2	8.300	2.254	24.50	17.00	14.80	23.40
K3	9.200	2.512	21.20	17.00	44.10	18.10
K4	6.500	1.524	24.60	18.00	56.20	16.70
K5	8.400	1.564	17.40	19.00	45.60	16.70
L1	8.600	5.072	22.40	16.00	19.90	25.50
L2	11.800	2.571	24.30	16.00	16.80	26.40
L4	8.600	2.042	24.30	16.00	17.80	25.00
L5	8.600	2.044	22.20	18.00	28.90	18.40
M1	15.500	3.841	19.60	17.00	17.10	21.10
M2	15.500	3.999	14.90	16.00	27.20	17.50
M3	17.700	3.575	22.40	18.00	16.80	23.00
M4	9.800	2.207	22.30	15.00	20.50	20.00
M5	5.800	1.323	21.60	15.00	16.10	24.10
N1	13.200	5.326	20.10	16.00	16.70	21.60
N2	13.900	4.152	19.60	16.00	27.90	23.50
N3	15.500	3.787	17.20	16.00	18.40	19.70
N4	9.900	2.266	18.80	18.00	18.10	19.90
N5	12.800	1.894	20.80	18.00	15.70	21.90
			Depth 90-120 cm			
J0	9.900	1.359	19.30	16.00	60.70	14.90
J1	7.100	1.914	24.30	15.00	62.60	14.90
J2	8.300	1.983	24.60	14.00	60.30	19.00
J3	8.400	1.813	23.50	16.00	57.00	17.10
J4	6.900	1.435	22.60	16.00	63.80	14.80
J5	9.400	1.170	16.50	16.00	60.50	15.90
K1	10.400	2.048	24.20	16.00	19.20	19.50
K2	7.400	1.904	24.50	16.00	22.60	22.80
K3	7.100	2.140	21.40	15.00	58.00	19.30
K4	7.500	1.506	28.90	17.00	60.30	17.80
K5	8.900	1.256	21.10	17.00	54.80	17.40
L1	8.300	0.864	22.70	15.00	18.30	22.50
L2	8.900	2.411	22.90	15.00	18.40	23.20
L4	7.400	1.618	23.30	15.00	17.90	19.10
L5	8.300	1.914	23.00	16.00	51.50	17.50
M1	9.400	2.147	22.20	16.00	20.00	17.80
M2	13.800	2.069	21.10	15.00	16.70	23.40
M3	7.000	1.577	20.80	16.00	36.30	17.60
M4	9.000	1.607	22.80	14.00	25.40	22.80
M5	5.800	1.603	21.90	14.00	16.20	22.80
N1	8.300	1.710	18.60	15.00	24.30	28.60
N2	11.000	0.548	18.50	14.00	32.00	21.70
N3	9.900	1.755	21.80	14.00	21.00	21.70
N4	6.200	1.520	21.80	16.00	34.40	17.10
N5	8.300	1.082	20.70	17.00	21.00	18.40

NOBLEFORD SALINITY SURVEY #3, SEPT 29-30, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm			
J0	36.400	4.311	24.50	15.00	29.70	19.60
J1	28.700	3.511	24.80	14.00	27.60	19.30
J2	26.600	4.242	24.30	15.00	26.90	19.30
J3	27.600	3.870	24.20	16.00	24.10	21.90
J4	26.700	3.511	25.90	16.00	32.40	20.00
J5	28.000	3.607	21.60	16.00	33.70	19.00
K1	30.500	3.682	21.20	19.00	29.40	18.00
K2	22.400	3.065	21.90	17.00	30.30	20.40
K3	24.300	2.466	19.30	17.00	42.10	20.90
K4	29.100	3.870	23.70	17.00	34.40	20.50
K5	36.000	4.276	19.70	17.00	26.00	19.90
L1	17.600	1.727	12.00	18.00	30.00	19.10
L2	23.700	3.465	21.40	19.00	32.10	23.00
L4	20.300	2.346	20.20	19.00	35.40	18.10
L5	25.400	3.030	17.40	19.00	30.10	22.20
M1	7.900	0.152	25.00	19.00	32.00	22.20
M2	6.700	0.216	5.20	20.00	33.60	19.80
M3	25.500	3.194	12.30	19.00	26.50	20.50
M4	16.400	2.378	19.60	19.00	29.70	19.60
M5	17.200	1.733	18.00	20.00	26.50	20.20
N1	11.000	2.612	7.30	19.00	17.20	19.90
N2	11.400	1.773	14.00	20.00	25.60	18.80
N3	25.800	1.250	10.90	20.00	26.80	19.10
N4	16.700	1.616	10.50	19.00	25.80	18.70
N5	18.200	1.578	13.30	20.00	29.30	18.00
			Depth 30-60 cm			
J0	17.000	2.159	20.00	16.00	48.20	18.00
J1	14.400	2.385	25.60	15.00	43.10	18.90
J2	17.400	2.390	26.00	15.00	45.10	16.10
J3	13.000	1.960	25.60	15.00	24.10	21.30
J4	8.800	1.795	23.60	16.00	48.50	16.70
J5	21.900	1.699	17.50	15.00	34.20	15.30
K1	15.000	3.208	30.20	18.00	19.80	21.00
K2	11.600	2.189	26.60	16.00	22.80	23.20
K3	16.000	2.540	27.50	16.00	34.80	18.90
K4	13.000	2.160	24.10	16.00	41.20	20.70
K5	19.500	2.274	22.90	16.00	30.70	20.40
L1	23.600	2.659	22.60	15.00	23.60	21.20
L2	18.900	2.705	23.10	16.00	24.20	23.60
L4	17.000	2.612	27.40	16.00	18.40	21.50
L5	15.000	3.068	25.80	15.00	16.40	17.80
M1	18.700	3.692	12.50	15.00	15.20	20.10
M2	13.900	2.436	9.00	16.00	33.70	21.10
M3	32.000	5.364	12.20	16.00	15.40	25.30
M4	15.300	2.580	22.70	15.00	15.50	24.40
M5	16.000	2.881	23.70	16.00	12.40	27.50
N1	24.000	5.810	17.20	15.00	13.70	24.00
N2	20.200	4.257	20.50	16.00	15.00	23.40
N3	32.000	3.756	14.90	16.00	15.20	18.70
N4	13.500	2.094	14.70	16.00	14.00	23.70
N5	14.200	2.106	14.20	16.00	21.10	16.80

NOBLEFORD SALINITY SURVEY #3, SEPT 29-30, 1979 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 60-90 cm			
J0	10.800	1.690	17.60	15.00	55.00	14.60
J1	10.500	1.682	24.80	14.00	50.70	19.60
J2	10.100	2.062	24.30	14.00	53.10	16.10
J3	11.600	2.330	24.30	15.00	42.20	17.20
J4	9.600	1.408	22.90	15.00	54.90	15.80
J5	10.300	1.408	12.20	15.00	50.20	14.30
K1	12.000	1.396	25.80	17.00	17.40	21.10
K2	7.400	2.114	22.90	15.00	14.80	23.40
K3	9.300	1.882	99.90	15.00	44.10	18.10
K4	8.200	1.887	22.80	16.00	56.20	16.70
K5	9.000	0.920	20.50	15.00	45.60	16.70
L1	12.300	2.592	22.20	14.00	19.90	25.50
L2	12.200	1.990	22.30	15.00	16.80	26.40
L4	10.700	2.209	23.30	15.00	17.80	25.00
L5	9.700	0.973	20.90	15.00	28.90	18.40
M1	19.100	2.471	18.30	14.00	17.10	21.10
M2	16.700	2.127	16.60	14.00	27.20	17.50
M3	18.700	0.913	20.30	15.00	16.80	23.00
M4	9.800	1.930	19.50	14.00	20.50	20.00
M5	8.700	0.744	19.90	14.00	16.10	24.10
N1	18.000	2.402	19.70	14.00	16.70	21.60
N2	15.000	1.338	19.10	14.00	27.90	23.50
N3	24.700	1.795	16.90	14.00	18.40	19.70
N4	11.600	2.119	16.40	14.00	18.10	19.90
N5	13.000	2.412	19.00	14.00	15.70	21.90
			Depth 90-120 cm			
J0	12.800	1.664	31.70	15.00	60.70	14.90
J1	9.300	1.894	22.40	14.00	62.60	14.90
J2	11.000	1.914	24.20	14.00	60.30	19.00
J3	12.600	1.848	23.80	14.00	57.00	17.10
J4	10.400	1.446	22.60	15.00	63.80	14.80
J5	6.700	0.654	15.00	14.00	60.50	15.90
K1	10.100	1.722	23.10	16.00	19.20	19.50
K2	7.700	2.456	24.80	15.00	22.60	22.80
K3	8.700	2.100	99.90	14.00	58.00	19.30
K4	9.000	1.727	22.30	15.00	60.30	17.80
K5	11.600	1.370	19.40	15.00	54.80	17.40
L1	8.400	2.846	22.40	14.00	18.30	22.50
L2	8.100	1.848	21.00	14.00	18.40	23.20
L4	11.800	1.977	22.60	14.00	17.90	19.10
L5	9.500	2.073	19.40	14.00	51.50	17.50
M1	11.700	2.105	21.80	14.00	20.00	17.80
M2	12.200	2.589	19.30	13.00	16.70	23.40
M3	11.300	1.353	20.30	14.00	36.30	17.60
M4	6.600	2.100	19.10	13.00	25.40	22.80
M5	5.700	1.810	20.60	13.50	16.20	22.80
N1	10.900	1.232	17.60	13.00	24.30	28.60
N2	12.200	2.276	19.00	13.00	32.00	21.70
N3	14.400	2.343	20.00	14.00	21.00	21.70
N4	7.300	1.151	18.20	13.00	34.40	17.10
N5	10.400	3.208	19.70	14.00	21.00	18.40

NOBLEFORD SALINITY SURVEY #4, APR 25-26, 1980 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm			
J0	28.200	4.932	25.00	13.50	29.70	19.60
J1	19.000	4.713	21.40	15.50	27.60	19.30
J2	21.000	3.607	30.30	13.00	26.90	19.30
J3	20.800	5.865	23.80	15.00	24.10	21.90
J4	21.800	4.551	24.70	16.00	32.40	20.00
J5	26.700	4.474	23.40	15.50	33.70	19.00
K1	19.000	4.909	19.30	17.00	29.40	18.00
K2	28.300	4.501	21.90	17.00	30.30	20.40
K3	13.300	4.524	15.30	17.50	42.10	20.90
K4	28.400	3.607	23.10	17.00	34.40	20.50
K5	29.700	6.895	24.60	17.50	26.00	19.90
L1	14.100	3.558	20.10	16.50	30.00	19.10
L2	15.700	3.870	21.50	16.50	32.10	23.00
L3	11.600	1.597	12.60	20.00	33.90	21.20
L4	28.700	3.388	20.40	16.00	35.40	18.10
L5	20.700	5.239	19.60	17.00	30.10	22.20
M1	6.000	2.030	20.70	20.00	32.00	22.20
M2	6.100	2.169	16.60	19.00	33.60	19.80
M3	16.800	6.737	17.00	18.00	26.50	20.50
M4	9.800	3.578	22.40	15.00	29.70	19.60
M5	20.800	4.242	21.30	16.00	26.50	20.20
N1	7.000	3.033	19.20	10.00	17.20	19.90
N2	12.600	6.380	27.10	11.00	25.60	18.80
N3	13.300	2.885	20.70	12.00	26.80	19.10
N4	13.600	3.957	19.90	12.00	25.80	18.70
N5	15.300	2.823	22.80	12.00	29.30	18.00
			Depth 30-60 cm			
J0	13.900	4.344	22.30	9.50	48.20	18.00
J1	9.600	2.241	22.00	10.00	43.10	18.90
J2	9.300	3.877	21.60	8.00	45.10	16.10
J3	11.100	2.349	22.00	9.00	24.10	21.30
J4	9.000	2.243	19.50	9.00	48.50	16.70
J5	22.600	1.064	20.10	9.00	34.20	15.30
K1	14.400	2.543	26.20	10.00	19.80	21.00
K2	18.700	2.223	26.90	10.50	22.80	23.20
K3	23.700	1.238	23.80	11.00	34.80	18.90
K4	12.900	3.187	26.30	10.50	41.20	20.70
K5	16.300	2.269	28.70	10.00	30.70	20.40
L1	18.600	4.314	24.40	10.00	23.60	21.20
L2	15.800	4.230	24.30	10.00	24.20	23.60
L3	13.400	2.145	18.60	12.50	25.50	22.20
L4	14.100	2.760	29.20	8.00	18.40	21.50
L5	11.600	1.635	27.50	9.00	16.40	17.80
M1	19.300	4.198	21.00	14.00	15.20	20.10
M2	13.700	2.393	21.50	12.00	33.70	21.10
M3	17.100	3.035	24.80	11.00	15.40	25.30
M4	6.200	1.910	25.10	9.00	15.50	24.40
M5	13.100	2.526	22.80	9.00	12.40	27.50
N1	20.300	5.417	19.80	8.50	13.70	24.00
N2	17.400	1.770	23.80	9.00	15.00	23.40
N3	19.000	6.407	23.90	10.00	15.20	18.70
N4	17.000	3.689	21.90	10.00	14.00	23.70
N5	8.400	2.613	23.20	9.00	21.10	16.80

NOBLEFORD SALINITY SURVEY #4, APR 25-26, 1980 - DRAINFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 60-90 cm			
J0	12.200	2.406	18.00	6.50	55.00	14.60
J1	9.000	2.517	17.10	7.00	50.70	19.60
J2	10.400	1.267	22.20	6.00	53.10	16.10
J3	10.000	1.590	21.80	6.00	42.20	17.20
J4	9.100	0.883	20.80	5.50	54.90	15.80
J5	10.400	2.475	15.60	6.00	50.20	14.30
K1	11.500	2.334	23.10	6.00	17.40	21.10
K2	10.900	2.483	25.00	7.00	14.80	23.40
K3	10.700	3.259	20.00	8.00	44.10	18.10
K4	9.600	2.242	20.90	7.00	56.20	16.70
K5	8.400	2.650	20.60	7.00	45.60	16.70
L1	10.200	2.715	25.90	7.00	19.90	25.50
L2	17.700	1.869	23.00	7.00	16.80	26.40
L3	10.000	3.644	18.40	9.00	32.40	19.80
L4	13.400	2.504	23.30	4.50	17.80	25.00
L5	11.800	2.717	22.50	6.00	28.90	18.40
M1	16.400	2.355	20.70	9.00	17.10	21.10
M2	20.300	1.930	21.50	8.00	27.20	17.50
M3	9.400	1.886	20.40	8.00	16.80	23.00
M4	12.800	3.068	20.60	6.00	20.50	20.00
M5	9.500	1.089	20.80	5.50	16.10	24.10
N1	14.600	3.181	22.60	6.00	16.70	21.60
N2	13.800	2.878	23.80	7.00	27.90	23.50
N3	10.200	0.458	21.10	7.00	18.40	19.70
N4	13.200	4.273	22.40	7.00	18.10	19.90
N5	15.700	2.421	23.40	6.00	15.70	21.90
			Depth 90-120 cm			
J0	13.800	1.162	19.60	5.00	60.70	14.90
J1	6.200	2.033	21.50	5.00	62.60	14.90
J2	10.200	2.557	21.10	4.00	60.30	19.00
J3	8.000	1.700	18.40	4.50	57.00	17.10
J4	6.100	1.047	22.00	4.00	63.80	14.80
J5	7.700	1.375	15.40	5.00	60.50	15.90
K1	13.300	1.622	21.90	4.50	19.20	19.50
K2	9.200	1.153	23.50	5.00	22.60	22.80
K3	8.300	1.439	21.80	6.00	58.00	19.30
K4	7.100	1.992	16.80	5.50	60.30	17.80
K5	7.800	0.378	20.50	5.00	54.80	17.40
L1	5.600	1.173	21.60	5.50	18.30	22.50
L2	13.700	0.411	21.40	5.00	18.40	23.20
L3	16.200	4.454	24.20	6.00	33.20	20.50
L4	7.500	1.392	21.40	3.00	17.90	19.10
L5	7.300	1.717	20.60	4.00	51.50	17.50
M1	11.100	0.757	22.40	6.50	20.00	17.80
M2	25.400	1.128	20.70	6.00	16.70	23.40
M3	12.800	-0.562	22.40	6.00	36.30	17.60
M4	10.000	1.724	21.70	5.00	25.40	22.80
M5	6.000	1.431	22.60	4.00	16.20	22.80
N1	14.500	2.781	20.60	5.00	24.30	28.60
N2	11.000	1.192	22.70	5.00	32.00	21.70
N3	10.000	2.702	20.40	6.00	21.00	21.70
N4	8.400	0.501	20.90	5.00	34.40	17.10
N5	9.600	3.123	23.10	4.50	21.00	18.40

NOBLEFORD SALINITY SURVEY #5, MAY 14-22, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm			
A1	21.600	5.198	31.90	17.00	25.30	22.10
A2	33.700	7.013	25.80	15.50	30.30	20.10
A3	22.100	4.110	23.40	12.00	34.80	17.10
B1	19.200	5.665	31.40	16.00	28.80	21.30
B2	17.400	4.946	29.00	9.00	33.00	20.30
B3	20.700	5.040	27.90	12.00	30.10	22.40
B4	19.700	6.032	30.50	12.00	30.90	18.00
B5	29.900	6.895	26.20	15.50	25.30	19.90
C1	13.100	2.599	46.80	10.00	34.60	18.10
C2	10.200	1.597	33.40	7.00	29.10	20.20
C3	15.500	4.364	37.10	11.50	26.20	17.30
C4	14.500	4.798	33.40	11.00	28.30	14.10
C5	13.200	3.381	28.80	13.00	25.60	17.00
D1	12.500	3.682	32.40	11.00	32.00	16.00
D2	16.400	3.273	58.30	7.00	29.50	16.50
D3	16.000	4.191	29.80	10.00	25.50	18.10
D4	13.800	2.075	34.70	8.50	26.50	19.90
D5	15.200	5.534	31.40	12.00	26.40	23.30
E1	11.100	3.083	34.10	9.00	30.40	17.60
E2	18.000	2.678	41.80	7.00	30.20	19.60
E3	14.700	4.437	30.00	8.50	29.60	20.70
E4	99.999	4.175	99.99	10.50	27.50	21.80
E5	13.900	3.652	29.80	13.00	25.60	20.00
			Depth 30-60 cm			
A1	15.400	3.444	33.80	13.00	21.30	16.20
A2	34.400	5.897	32.80	8.50	13.10	19.30
A3	25.800	3.942	27.10	9.00	41.40	14.20
B1	19.500	3.019	35.60	13.00	20.20	16.90
B2	20.200	4.898	33.70	7.00	21.30	13.30
B3	20.200	4.732	33.80	9.00	17.30	17.60
B4	16.600	3.084	28.60	9.00	33.40	19.00
B5	20.500	3.781	32.80	10.00	24.30	13.30
C1	9.800	2.359	37.10	8.00	36.90	13.10
C2	12.200	3.529	37.80	5.00	20.50	17.30
C3	11.900	2.626	40.70	9.00	13.10	20.00
C4	18.200	3.442	30.70	8.00	32.90	19.00
C5	12.900	4.585	32.50	9.00	18.90	19.10
D1	10.400	1.164	39.30	8.00	40.00	14.80
D2	11.500	1.149	42.40	2.50	31.40	17.90
D3	14.900	4.139	35.70	8.50	14.10	20.60
D4	17.300	4.781	31.00	6.50	20.00	22.10
D5	20.200	5.294	35.50	8.50	14.90	23.20
E1	10.400	2.697	35.80	7.00	30.40	23.20
E2	13.500	1.404	35.50	2.00	37.90	17.40
E3	11.200	2.271	34.60	7.00	33.80	22.20
E4	12.800	3.605	32.90	9.00	17.90	23.20
E5	17.000	2.330	33.30	9.00	19.40	21.70

NOBLEFORD SALINITY SURVEY #5, MAY 14-22, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 60-90 cm			
A1	11.000	1.519	26.70	9.00	40.60	12.90
A2	22.500	0.902	29.50	5.00	27.50	15.40
A3	14.800	2.685	25.60	7.00	51.60	17.10
B1	19.000	2.413	32.10	9.00	44.00	12.90
B2	20.600	3.092	32.70	6.00	16.10	20.90
B3	16.700	3.899	30.60	7.00	12.70	22.50
B4	18.300	2.995	18.70	7.50	43.10	18.10
B5	17.100	1.138	29.40	7.50	14.60	19.70
C1	9.100	1.252	34.30	6.00	28.70	16.80
C2	9.800	2.149	39.00	5.00	14.50	21.00
C3	11.300	3.114	34.60	7.50	24.20	19.70
C4	16.600	2.764	31.20	6.50	36.80	14.20
C5	12.000	2.042	31.10	7.00	12.40	20.30
D1	8.800	2.741	31.90	6.00	25.70	15.40
D2	10.000	1.161	33.80	1.00	18.60	22.70
D3	15.400	2.428	32.30	6.00	28.70	20.60
D4	16.700	2.417	30.80	5.50	32.10	17.80
D5	20.800	3.824	33.90	7.00	11.50	23.50
E1	8.300	1.906	37.00	6.00	21.60	20.30
E2	12.400	2.734	43.20	-0.50	24.40	20.50
E3	10.400	2.358	44.50	5.00	42.60	16.00
E4	11.700	1.898	30.00	7.00	13.50	24.50
E5	11.500	3.423	34.70	7.50	11.70	25.40
			Depth 90-120 cm			
A1	9.500	1.867	29.60	6.00	40.90	16.20
A2	13.800	2.068	25.00	5.00	35.50	17.90
A3	11.600	1.263	22.70	8.50	58.90	16.20
B1	17.700	1.095	29.90	5.00	20.60	32.60
B2	22.300	3.284	34.60	5.00	13.30	24.30
B3	15.300	1.977	28.10	6.00	35.60	15.10
B4	15.500	2.149	25.60	6.50	32.40	12.70
B5	11.300	-0.310	25.40	6.00	33.10	14.40
C1	10.400	1.326	33.10	5.00	31.20	10.70
C2	11.400	2.925	40.60	4.00	19.80	18.20
C3	11.100	1.304	33.10	6.50	16.00	27.90
C4	16.900	1.868	32.70	5.50	44.10	15.80
C5	99.999	1.648	99.99	6.00	31.60	17.50
D1	9.200	1.481	34.70	5.00	21.20	18.10
D2	8.800	1.297	30.70	0.00	10.70	25.60
D3	13.800	2.438	28.60	5.50	36.20	17.40
D4	15.800	1.799	31.10	5.00	53.80	17.50
D5	20.900	1.820	34.10	6.00	16.60	19.50
E1	3.700	1.654	35.50	5.00	14.50	25.40
E2	11.200	1.196	37.90	-1.00	36.50	18.40
E3	9.300	1.114	29.50	4.00	37.30	21.30
E4	12.100	1.878	32.20	6.00	25.40	18.20
E5	9.600	2.407	33.40	6.50	19.80	21.10

NOBLEFORD SALINITY SURVEY #6, SEPT 25, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 0-30 cm			
A1	32.500	3.356	22.80	14.00	25.30	22.10
A2	39.500	3.421	22.00	14.00	30.30	20.10
A3	32.700	2.218	17.70	15.00	34.80	17.10
B1	33.800	4.311	25.60	14.00	28.80	21.30
B2	35.000	3.101	21.70	14.00	33.00	20.30
B3	23.500	2.501	18.80	14.00	30.10	22.40
B4	23.500	2.356	19.60	15.00	30.90	18.00
B5	32.300	2.851	17.20	16.00	25.30	19.90
C1	19.800	3.101	29.40	13.00	34.60	18.10
C2	15.000	0.942	21.50	16.00	29.10	20.20
C3	21.700	3.399	28.10	14.50	26.20	17.30
C4	22.200	0.869	19.30	15.50	28.30	14.10
C5	26.500	2.147	22.30	15.00	25.60	17.00
D1	23.000	3.293	31.50	15.00	32.70	16.80
D2	24.500	3.356	34.00	14.50	29.50	16.50
D3	21.200	2.962	21.10	15.50	25.50	18.10
D4	25.800	1.744	22.30	14.00	26.50	19.90
D5	7.200	0.067	13.10	16.00	26.40	23.30
E1	21.600	2.835	27.70	14.00	30.40	17.60
E2	26.800	3.682	28.10	15.00	30.20	19.60
E3	28.000	3.233	25.10	13.50	29.60	20.70
E4	23.700	2.443	21.50	14.50	27.50	21.80
E5	22.800	2.031	19.10	15.00	25.60	20.00
			Depth 30-60 cm			
A1	22.000	1.796	19.10	14.00	21.30	16.20
A2	26.800	2.609	26.40	14.00	13.10	19.30
A3	20.900	1.492	16.00	15.00	41.40	14.20
B1	14.200	1.931	26.70	13.00	20.20	16.90
B2	25.000	2.667	25.30	13.00	21.30	13.30
B3	23.200	3.741	25.00	13.00	17.30	17.60
B4	18.700	1.380	17.30	14.00	33.40	19.00
B5	19.000	1.973	19.40	15.00	24.30	13.30
C1	9.400	1.811	31.20	12.00	36.90	13.10
C2	10.400	2.236	42.60	13.00	20.50	17.30
C3	13.000	2.917	33.00	13.00	13.10	20.00
C4	19.700	2.031	16.40	12.00	32.90	19.00
C5	18.700	2.633	22.50	13.00	18.90	19.10
D1	10.000	1.665	31.90	13.00	40.00	14.80
D2	9.500	1.846	24.10	12.50	31.40	17.90
D3	19.000	2.806	27.20	13.50	14.10	20.60
D4	19.000	1.724	21.50	12.50	20.00	22.10
D5	13.000	0.361	16.60	13.00	14.90	23.20
E1	13.500	1.311	25.30	12.50	30.40	23.20
E2	12.500	2.416	23.30	13.00	37.90	17.40
E3	17.000	1.047	24.40	12.00	33.80	22.20
E4	13.600	1.607	20.40	12.00	17.90	23.20
E5	17.600	1.091	17.40	13.00	19.40	21.70

NOBLEFORD SALINITY SURVEY #6, SEPT 25, 1979 - WESTFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 60-90 cm			
A1	15.000	1.238	13.50	14.00	40.60	12.90
A2	16.500	1.656	18.10	14.00	27.50	15.40
A3	10.900	0.943	13.30	14.00	51.60	17.10
B1	9.500	1.675	18.20	13.00	44.00	12.90
B2	18.800	3.877	24.30	12.00	16.10	20.90
B3	14.200	2.044	25.80	12.50	12.70	22.50
B4	16.700	2.225	19.00	13.00	43.10	18.10
B5	13.600	1.272	20.40	14.00	14.60	19.70
C1	8.600	1.256	29.80	11.50	28.70	16.80
C2	9.300	3.452	27.30	12.50	14.50	21.00
C3	7.900	1.370	25.00	12.00	24.20	19.70
C4	15.000	0.613	14.90	12.00	36.80	14.20
C5	12.000	0.923	21.10	12.00	12.40	20.30
D1	12.800	1.432	32.80	12.00	25.70	15.40
D2	6.800	1.599	21.60	12.00	18.60	22.70
D3	12.600	0.547	20.30	13.00	28.70	20.60
D4	12.900	2.058	17.50	12.00	32.10	17.80
D5	14.300	1.267	19.40	12.50	11.50	23.50
E1	11.300	1.950	32.30	12.00	21.60	20.30
E2	9.500	1.819	23.30	13.00	24.40	20.50
E3	14.000	1.888	23.80	11.50	42.60	16.00
E4	11.600	1.476	18.80	11.50	13.50	24.50
E5	14.700	1.744	17.40	12.00	11.70	25.40
			Depth 90-120 cm			
A1	7.300	0.778	12.00	14.00	40.90	16.20
A2	9.400	1.458	16.30	14.00	35.50	17.90
A3	7.600	1.051	11.30	14.00	58.90	16.20
B1	5.900	1.227	20.90	13.00	20.60	32.60
B2	10.400	2.411	21.90	11.50	13.30	24.30
B3	8.500	1.914	23.40	12.00	35.60	15.10
B4	14.800	1.955	17.60	13.00	32.40	12.70
B5	8.000	0.220	13.90	14.00	33.10	14.40
C1	7.900	1.096	23.60	11.00	31.20	10.70
C2	8.300	0.634	23.10	12.00	19.80	18.20
C3	5.700	1.958	21.90	12.00	16.00	27.90
C4	10.000	2.251	15.30	11.50	44.10	15.80
C5	11.000	1.561	16.00	12.00	31.60	17.50
D1	8.800	1.082	28.70	11.50	21.20	18.10
D2	6.000	1.359	19.80	11.50	10.70	25.60
D3	9.700	0.949	18.50	12.50	36.20	17.40
D4	8.900	1.738	16.80	11.50	53.80	17.50
D5	8.200	2.325	20.60	12.00	16.60	19.50
E1	10.100	1.272	30.40	11.50	14.50	25.40
E2	8.200	1.727	20.40	12.50	36.50	18.40
E3	12.100	1.000	23.40	11.00	37.30	21.30
E4	9.400	2.050	20.00	11.00	25.40	18.20
E5	9.000	1.450	18.30	11.50	19.80	21.10

NOBLEFORD SALINITY SURVEY #7, APR 25-26, 1980 - HEDGEFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 0-30cm			
V1	11.900	2.913	24.50	13.50	31.10	26.40
V3	19.700	4.382	25.50	14.00	26.60	28.50
V5	0.830	0.466	16.80	15.00	38.00	22.20
V7	0.900	0.223	12.80	15.50	41.00	23.30
V10	0.620	0.179	16.20	16.50	34.50	25.40
X1	14.380	4.734	23.10	12.50	33.60	25.40
X3	18.400	4.978	25.30	15.00	31.70	31.60
X5	2.000	0.315	15.30	16.50	41.70	20.20
X7	0.710	0.220	17.30	17.00	36.30	24.30
X10	0.740	0.228	10.80	17.00	51.70	16.40
Z1	27.700	8.284	26.90	14.00	33.80	32.00
Z3	18.300	3.377	23.80	12.50	32.00	28.00
Z5	0.940	0.320	23.20	15.50	31.70	25.70
Z7	0.560	0.200	16.70	17.00	33.80	25.70
Z10	0.550	0.218	18.10	17.00	29.70	26.80
Z11	0.850	0.291	18.00	17.00	29.70	37.10
			Depth 30-60cm			
V1	19.400	5.563	25.80	9.00	25.20	29.40
V3	27.200	2.608	19.40	10.00	31.00	32.50
V5	1.210	0.522	12.80	10.50	30.00	25.30
V7	0.820	0.153	12.60	11.00	44.40	22.20
V10	0.430	0.093	7.00	12.00	46.10	21.10
X1	20.000	5.258	28.30	9.00	23.80	33.50
X3	23.800	6.312	25.60	10.00	28.90	27.30
X5	2.380	0.449	16.50	12.00	42.00	20.10
X7	0.740	0.178	12.80	12.00	49.90	17.00
X10	0.700	0.264	10.50	11.50	39.50	21.50
Z1	33.000	2.370	18.90	10.00	42.40	28.70
Z3	11.300	1.573	19.00	8.00	42.40	26.70
Z5	2.750	0.338	9.60	10.50	50.60	18.40
Z7	0.620	0.140	15.60	10.00	27.90	30.80
Z10	0.620	0.176	14.10	12.00	22.70	28.70
Z11	0.710	0.451	13.10	12.50	23.80	41.10

NOBLEFORD SALINITY SURVEY #7, APR 25-26, 1980 - HEDGEFIELD

* * * * * * Data for Variables in Regression Analysis * * * * * *

Gridpoint	ECE	ECX	H2O	TEMP	SAND	CLAY
			Depth 60-90 cm			
V1	15.700	2.786	21.90	6.00	37.70	22.10
V3	18.400	1.761	23.30	7.50	34.20	36.50
V5	7.430	0.494	8.30	8.00	34.20	21.10
V7	0.760	0.134	7.40	9.50	46.60	15.90
V10	0.580	0.127	4,80	10.00	50.30	19.00
X1	16.500	3.073	25.10	6.00	26.00	29.30
X3	1.720	-0.076	22.00	7.00	26.00	38.60
X5	3.510	0.628	12.80	8.50	44.20	15.90
X7	1.040	0.148	10.00	10.00	44.80	17.30
X10	0.710	0.048	6.50	9.50	47.90	18.40
Z1	27.300	4.721	23.60	7.00	30.10	40.00
Z3	10.390	2.247	16.70	5.00	33.20	36.90
Z5	5.380	0.383	11.00	8.00	44.50	18.40
Z7	0.520	0.080	5.90	8.00	48.70	18.40
Z10	0.620	0.137	5.50	9.00	39.40	18.40
Z11	0.730	0.335	13.80	10.00	21.90	39.00
			Depth 90-120cm			
V1	15.000	2.550	21.10	5.00	53.20	19.00
V3	9.780	1.569	12.70	6.00	38.30	25.20
V5	4.360	0.654	9.20	6.50	44.50	14.90
V7	0.630	0.174	6.40	7.00	44.20	12.80
V10	0.530	0.173	7.00	7.00	42.00	17.30
X1	15.000	1.467	23.10	5.00	36.30	24.20
X3	21.500	3.046	19.00	5.50	20.80	40.70
X5	2.320	0.660	10.10	7.00	48.30	14.90
X7	0.960	0.262	8.90	9.00	47.90	17.30
X10	0.720	0.108	6.90	7.00	42.00	17.30
Z1	24.700	0.181	34.60	5.00	20.80	45.20
Z3	8.420	0.899	29.50	4.00	21.90	48.30
Z5	4.200	0.303	9.30	6.50	47.60	18.40
Z7	0.740	0.112	5.80	6.00	60.00	16.30
Z10	1.050	0.185	8.80	7.00	42.50	17.30
Z11	0.530	0.643	37.10	7.50	32.20	27.60

APPENDIX B

STATISTICAL DATA FOR SALINITY SURVEY

DRAINFIELD MAY, 1979

	0-30 cm		0-60 cm		0-90 cm		0-120 cm	
	ECe	ECe'	ECe	ECe'	ECe	ECe'	ECe	ECe'
mean	15.78	15.78	15.62	15.62	14.78	14.78	13.97	14.00
std. deviation	6.50	5.25	4.37	3.54	3.04	2.42	2.64	2.14
range	3.4-24.9	7.4-24.2	7.5-24.3	10.2-21.7	9.5-20.1	10.6-19.9	8.8-19.8	10.2-19.1

DRAINFIELD AUGUST, 1979

	0-30 cm		0-60 cm		0-90 cm		0-120 cm	
	ECe	ECe'	ECe	ECe'	ECe	ECe'	ECe	ECe'
mean	24.02	24.14	19.80	19.80	16.82	16.81	14.74	14.73
std. deviation	8.70	7.66	5.32	3.26	3.75	2.03	2.88	1.72
range	7.8-38.8	12.1-37.1	12.1-31.3	11.1-24.9	12.3-26.5	10.6-19.8	11.2-21.6	9.0-17.1

DRAINFIELD SEPTEMBER 1979

	0-30 cm		0-60 cm		0-90 cm		0-120 cm	
	ECe	ECe'	ECe	ECe'	ECe	ECe'	ECe	ECe'
mean	22.40	22.39	20.09	20.08	17.54	17.54	15.64	15.63
std. deviation	7.93	6.92	4.71	3.28	3.62	2.24	2.94	1.69
range	6.7-36.4	7.5-32.0	11.3-28.9	14.6-25.2	13.1-27.5	12.7-23.0	11.9-24.2	11.0-18.5

DRAINFIELD APRIL, 1980

	0-30 cm		0-60 cm		0-90 cm		0-120 cm	
	ECe	ECe'	ECe	ECe'	ECe	ECe'	ECe	ECe'
mean	18.01	18.02	16.44	16.43	14.95	14.95	13.78	13.77
std. deviation	7.29	5.04	4.06	2.27	2.41	1.11	1.91	0.31
range	6.0-29.7	4.6-27.1	8.0-24.6	12.4-21.2	9.6-19.9	12.7-17.6	9.7-17.0	13.0-14.3

WESTFIELD MAY, 1979

	0-30 cm		0-60 cm		0-90 cm		0-120 cm	
	ECe	ECe'	ECe	ECe'	ECe	ECe'	ECe	ECe'
mean	17.38	17.38	16.78	16.78	15.88	15.88	15.22	15.23
std. deviation	5.71	4.54	5.40	4.51	4.78	3.94	4.27	3.62
range	10.2-33.7	9.03-26.29	10.8-34.0	10.5-27.0	9.9-30.2	9.3-22.6	8.4-26.1	8.8-21.1

WESTFIELD SEPTEMBER, 1979

	0-30 cm		0-60 cm		0-90 cm		0-120 cm	
	ECe	ECe'	ECe	ECe'	ECe	ECe'	ECe	ECe'
mean	25.3	25.3	21.0	21.0	18.2	18.2	15.9	15.9
std. deviation	6.98	5.74	5.41	4.33	4.23	3.67	3.34	2.65
range	7.2-39.5	11.6-33.9	10.1-33.1	9.4-27.3	11.5-27.6	12.1-25.0	10.7-23.0	11.0-20.3

HEDGEFIELD APRIL, 1980

	0-30 cm		0-60 cm		0-90 cm		0-120 cm	
	ECe	ECe'	ECe	ECe'	ECe	ECe'	ECe	ECe'
mean	7.4	7.4	8.3	8.3	7.8	7.8	7.6	7.6
std. deviation	9.31	9.12	10.30	9.85	9.33	9.00	8.87	8.59
range	0.55-27.0	-0.41-28.8	0.52-30.3	-2.18-26.4	0.54-29.3	-1.56-27.0	0.54-28.2	-1.31-24.2

APPENDIX C

* * * * * * * * * * * * * * * * * * LOCATION A * * * * * * * * * * * * * * * * * *

Year - 1978

Date	ECe(Hedgfl)	ECe(Rhoades)	ECe(Sensor)	%H20	Salt.gm(Hf)	Salt.gm(Rh)	Salt.gm(Sen)
6/19	13.24	23.40	30.0	34.6	116.5	208.1	267.6
6/26	9.15	18.38	24.0	33.2	76.4	156.2	204.8
7/04	10.85	23.03	23.0	31.9	87.5	188.7	188.5
7/14	13.33	27.90	30.0	32.8	111.2	235.7	253.6
7/20	No Data	No Data	31.0	32.7	No Data	No Data	261.4
7/24	No Data	No Data	32.0	32.7	No Data	No Data	269.9
7/31	No Data	No Data	25.0	32.2	No Data	No Data	207.0
8/09	No Data	No Data	24.0	31.8	No Data	No Data	196.2
8/14	No Data	No Data	27.0	31.5	No Data	No Data	219.0
8/18	13.57	25.55	30.0	32.6	112.5	214.3	252.1
8/21	17.25	32.55	31.0	33.6	148.2	282.1	268.6
			Year - 1979				
5/28	15.22	27.81	No Data	30.1	116.8	215.6	No Data
6/04	14.26	27.67	No Data	28.6	103.9	203.8	No Data
6/11	17.82	35.69	25.0	28.3	129.0	260.8	182.0
6/18	16.68	33.68	33.0	28.7	122.3	249.4	244.4
6/25	14.28	29.44	35.0	27.5	100.0	208.6	248.5
7/04	15.69	32.67	40.0	26.2	104.9	220.8	270.9
7/09	9.19	22.61	44.0	25.4	58.7	147.5	289.1
7/16	13.14	29.81	50.0	24.8	82.8	190.5	321.0
7/23	20.83	45.73	30.0	22.9	122.4	270.9	177.1
7/30	8.08	19.12	27.0	22.8	46.1	111.7	158.5
8/08	No Data	No Data	27.0	22.0	No Data	No Data	152.9
8/13	No Data	No Data	28.0	22.0	No Data	No Data	158.7
8/20	8.45	21.17	29.0	20.8	44.1	113.0	155.4
8/27	13.43	28.03	27.0	29.3	100.1	211.5	203.7

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Year - 1979

Date	ECe(Hedgfl)	ECe(Rhoades)	ECe(Sensor)	%H20	Salt.gm(Hf)	Salt.gm(Rh)	Salt.gm(Sen)
5/28	11.47	19.68	No Data	26.9	78.1	135.7	No Data
6/04	9.48	17.93	No Data	23.8	56.8	109.2	No Data
6/11	10.67	19.40	13.6	29.6	79.8	147.1	102.4
6/18	10.41	20.63	15.0	25.4	66.8	134.4	97.1
6/25	8.74	18.73	16.4	21.7	47.6	104.1	90.9
7/04	5.19	11.59	17.1	19.7	25.0	57.8	86.1
7/09	3.80	13.14	17.4	19.4	17.6	64.8	86.3
7/16	4.86	14.29	17.6	19.1	22.6	69.5	86.0
7/23	4.71	15.13	15.0	18.1	20.7	69.8	69.2
7/30	2.70	8.99	14.8	18.3	11.3	41.3	69.0
8/08	No Data	No Data	14.0	18.3	No Data	No Data	65.2
8/13	No Data	No Data	14.5	18.4	No Data	No Data	68.0
8/20	1.79	8.49	14.2	17.4	6.7	37.0	62.9
8/27	6.43	13.78	8.6	27.5	43.8	96.4	59.3

* * * * * * * * * * * * * * * * * * LOCATION C * * * * * * * * * * * * * * * * * *

Year - 1979

Date	ECe(Hedgfl)	ECe(Rhoades)	ECe(Sensor)	%H20	Salt.gm(Hf)	Salt.gm(Rh)	Salt.gm(Sen)
5/28	7.54	9.62	No Data	30.4	57.2	73.7	No Data
6/04	6.21	9.52	No Data	28.8	44.2	69.0	No Data
6/11	1.74	6.79	7.1	25.7	9.5	43.3	45.4
6/25	-0.76	6.30	2.9	20.5	0.0	31.9	13.8
7/04	1.04	7.34	3.2	21.5	4.0	39.3	16.1
7/09	3.43	12.42	2.4	19.0	15.4	59.9	10.3
7/18	-2.11	4.31	2.2	17.6	0.0	18.3	8.6
7/23	-3.99	3.38	1.7	16.2	0.0	12.9	5.8
7/30	-2.41	1.54	1.9	16.3	0.0	5.2	6.7
8/08	No Data	No Data	1.7	15.5	No Data	No Data	5.6
8/13	No Data	No Data	1.9	15.7	No Data	No Data	6.5
8/20	-3.03	1.19	1.8	15.2	0.0	3.4	5.9

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Year - 1979

Date	ECe(Hedgfl)	ECe(Rhoades)	ECe(Sensor)	%H20	Salt.gm(Hf)	Salt.gm(Rh)	Salt.gm(Sen)
5/16	14.13	22.01	No Data	30.2	108.7	170.7	No Data
5/28	11.79	23.43	No Data	25.9	77.4	155.9	No Data
6/04	6.99	13.37	No Data	24.1	41.9	81.9	No Data
6/11	8.14	18.11	31.0	23.1	47.1	107.1	184.6
6/18	23.04	49.13	34.0	22.9	135.6	291.2	200.9
6/25	11.58	27.05	35.0	22.2	65.1	154.6	200.6
7/04	3.89	12.88	32.0	21.4	19.9	70.0	176.6
7/09	4.21	15.56	28.0	20.6	20.9	81.8	148.6
7/16	6.30	16.91	27.0	20.1	31.3	86.9	139.7
7/23	14.10	34.69	26.0	19.8	71.1	177.3	132.5
7/30	11.80	29.28	27.0	19.6	58.6	147.9	136.2
8/08	No Data	No Data	26.0	19.7	No Data	No Data	131.8
8/13	No Data	No Data	27.0	19.8	No Data	No Data	137.6
8/20	3.67	14.00	29.0	18.5	16.1	65.9	138.2
8/27	9.06	21.57	33.0	28.9	65.8	160.0	246.1

* * * * * * * * * * * * * * * * * * LOCATION E * * * * * * * * * * * * * * * * * *

Year - 1979

Date	ECe(Hedgfl)	ECe(Rhoades)	ECe(Sensor)	%H20	Salt.gm(Hf)	Salt.gm(Rh)	Salt.gm(Sen)
5/16	29.45	59.88	No Data	32.9	249.7	510.5	No Data
5/28	28.44	57.83	No Data	32.4	237.4	485.5	No Data
6/04	27.31	55.48	No Data	32.2	226.4	462.8	No Data
6/11	26.81	54.77	36.0	31.7	218.8	449.7	294.7
6/18	28.26	57.83	39.0	32.4	235.9	485.5	326.5
6/25	26.26	54.11	44.0	31.6	213.6	442.9	359.6
7/04	24.14	49.85	48.0	31.4	194.9	405.2	390.1
7/09	25.42	53.04	48.0	30.8	201.4	423.1	382.6
7/16	24.68	51.38	50.0	30.7	194.8	408.4	397.4
7/23	27.59	57.28	54.0	30.8	218.8	457.1	430.8
7/30	No Data	No Data	58.0	30.9	No Data	No Data	464.4
8/08	No Data	No Data	61.0	30.2	No Data	No Data	477.5
8/13	No Data	No Data	61.0	30.3	No Data	No Data	479.0
8/20	16.77	36.66	74.0	30.1	129.0	285.0	577.8
8/27	18.76	39.93	58.0	30.9	148.5	318.9	464.4

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Year - 1979

Date	ECe(Hedgfl)	ECe(Rhoades)	ECe(Sensor)	%H20	Salt.gm(Hf)	Salt.gm(Rh)	Salt.gm(Sen)
5/28	3.15	1.49	No Data	13.1	9.7	4.0	No Data
6/04	1.32	0.93	No Data	10.5	2.7	1.7	No Data
6/11	-2.43	0.28	No Data	9.1	0.0	0.0	No Data
6/18	-1.62	0.30	No Data	10.3	0.0	0.0	No Data
6/25	-6.37	0.45	No Data	8.5	0.0	0.3	No Data
7/04	-3.29	0.25	No Data	7.4	0.0	0.0	No Data
7/09	-8.07	0.09	No Data	7.0	0.0	0.0	No Data
7/16	-5.53	-0.09	No Data	6.7	0.0	0.0	No Data
7/23	-4.72	0.24	No Data	6.4	0.0	0.0	No Data
7/30	-2.90	-0.10	No Data	6.4	0.0	0.0	No Data
8/20	-6.27	-0.08	No Data	5.9	0.0	0.0	No Data
8/27	-2.25	0.18	No Data	17.3	0.0	0.0	No Data